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THIS ISSUE OF THE BULLETIN
IS DEDICATED TO THE MEMORY OF

Milton H. Friend

A FORMER STUDENT
AND GENEROUS PATRON OF THE
MARINE SCIENCES

1896-1952

BULLETIN OF MARINE SCIENCE OF THE GULF AND CARIBBEAN

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THE OCCURRENCE AND VERTICAL DISTRIBUTION OF THE EUPHAUSIACEA OF THE FLORIDA CURRENT¹

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ABSTRACT

The vertical distributions of the Euphausiacea present in the Florida Current are described. Light and temperature are shown to influence the day levels while the vertical distribution at night is shown to be under the control of light. During the dawn and dusk periods the paths of descending and ascending concentrations of the two most abundant species follow closely the lines of increasing and decreasing illumination values. The seasonal distribution of five species is described and the importance of light and temperature upon geographical variation of vertical distributions is discussed.

INTRODUCTION

Our knowledge of the Euphausiacea of the western area of the North Atlantic dates back to the time of Ortmann (1893) who recorded a number of species from this area. Further records have been given by Hansen (1915) from the Western Atlantic, by Colosi (1917) from the Caribbean and by Bigelow (1926) from the off-shore waters of the Gulf of Maine. Tattersall (1926) has listed the species which occurred from Chesapeake Bay to the northern end of the Bahama Bank and has given information on the biology and vertical distribution of the group. Leavitt (1935, 1938) working in the deep waters off the Woods Hole region found that out of twenty species of Euphausids taken, fifteen were captured in the upper 400 meters. Moore (1949) has some data on the occurrence and vertical distribution of the Euphausids in the Bermuda area of the Atlantic and Einarsson (1945) has noted the occurrence of a few species from the Florida area in North Atlantic waters. Ruud (1936) has listed a number of species from the Mediterranean which also occur in the Florida area. He has much information on breeding and spawning of Medi-

¹Contribution No. 132 from the Marine Laboratory, University of Miami.

terranean forms and has stressed the importance of temperature in determining vertical and geographical distribution.

Diurnal migration has been noted in a number of Euphausiid species by Tattersall (1924), Macdonald (1927), Hickling (1925), Lebour (1924), Moore (1949) and others. Variation in such behaviour between different stages of the same species has been noted by Lebour (1925) and also by Frazer (1936). Frazer found that the eggs and nauplii of *Euphausia superba* were taken only in deep water while there were pronounced vertical migrations of calyptopis and early furcilia stages. Ruud (1932) on the other hand found that while adults of *Euphausia superba* were surface forms there was no evidence of larvae being found below the surface.

Quite recently interest has been aroused in the Euphausiacea as a possible source of mid-water sound echoes obtained on certain types of echo-sounders carried by ships and which have come to be called the "Deep Scattering Layer." Most authors are agreed that some part of the pelagic zooplankton is the cause of this phenomenon. Bathypelagic fishes have been suggested as possible sources of the scattering layer by Marshall (1951) and squid by Lyman (1948). Attention has been given to the planktonic crustacea and especially the Euphausiacea by Dietz (1948), Hersey and Moore (1948), Boden (1950) and Tucker (1951).

Studies were begun in 1950 by Moore et al (1952a, 1952b) to investigate the relationship between the Euphausiacea and the scattering layer. The study of the Euphausiacea is part of an investigation of the scattering layer carried out by the Marine Laboratory for the Office of Naval Research under contract number NObsr-57146. I wish to express my thanks to all the members of the laboratory who assisted in the field work and to Dr. H. B. Moore who helped with advice and encouragement. The completion of the work was made possible by a Fellowship from the National Research Council of Canada.

METHODS AND MATERIALS

The program of field work was designed to sample the plankton population, from the surface to the bottom, as often as possible throughout a twenty-four hour period. At the position chosen for the stations there were depths of 400-450 fathoms. The hauls were made at 100 meter wire intervals; each series from the surface to the bottom contained 9 samples. For the surface hauls and hauls at 100 and 200 meters wire length, three nets were placed on the cable together,

thus sampling three depths simultaneously. Two nets were placed on the wire, 100 meters apart for the other samples of each series. Hauls were of half hour duration with the exception of the surface set which were only of twenty minutes duration. Upon the completion of each haul the plankton samples were collected in jars and preserved in a 5% solution of formalin neutralized with borax.

The first twenty-four hour station was completed in October of 1952. Stations were made about once a month thereafter. The station numbers with their dates are as follows: SL.8—October 16, 17; SL.9—December 4,5; SL.10—December 9,10; SL.11—January 22,23; SL.13—February 26,27; SL.14—March 19,20; SL.15—April 23,24; SL.16—May 21,22; SL.17—June 11,12; SL.18—July 1,2; SL.19—August 13,14.

All stations except SL. 8,9 and 10 were made in small area a few miles west of Gun Cay light in the Straits of Florida, about $79^{\circ}25'W$. long. and $25^{\circ}40'$ lat. Because of the high velocity of the Florida Current, even at that position well out of the axis, the vessel tended to be carried very quickly away from the station position and into shallower water. Due to the fact that the area in which there was a sufficient depth of water was rather small and also because it was more desirable and convenient to maintain a position near a harbor in case of bad weather, the vessel steamed back to the original station position at the end of each plankton haul. The position was reckoned each time from the light on Gun Cay and the visible nearby cays. Thus the hauls for the twenty-four hour period and for all stations except those mentioned above were made in an area a few miles in diameter.

Stations SL. 8,9 and 10 were made further west, closer to the axis of the Florida Current. The area covered on these stations was somewhat larger than the area involved in the other stations because of the difficulty of returning to the one position in the absence of visible landmarks and the increased velocity of the current. However the same depths, 400-450 fathoms, were maintained as in the other stations.

The plankton nets used were modified from the Discovery type net (see Kemp, Hardy and Mackintosh, 1929). Methods and accessory devices were the same as those described by Miller, Moore and Kvammen (1953).

A combined depth distance meter described by Miller et al (1953) was used with all hauls and attached to the cable just below the bottom net. This meter registered the depth at which the net had been

towed and the distance towed on a smoked glass slide. The metering of the distance travelled was applied as a correction so that all plankton counts were reduced to the equivalent of a one mile tow.

It was difficult to be certain of the velocity of the current at each station since it was so variable. However, it was estimated that the nets were towed at speeds from two to three knots 3.70—5.55 kilometers/hr. The surface hauls were probably towed slightly faster than deep tows. This is about maximum speed for towing and was probably fast enough to prevent loss of most forms as large as Euphausiids.

Temperature and salinity data were obtained with Nansen bottles and reversing thermometers using standard oceanographic techniques. Extinction coefficients of the water were calculated from Secchi disk readings. Since photocell measurements have not been made at depths of several hundred fathoms it was necessary to calculate the illumination there. A method of calculation of lines of equal illumination throughout a twenty-four hour period has been described by Moore (1950). An arbitrary value of one hundred for overhead sunlight immediately above the water surface has been chosen.

The key used for the identification of the adults of the species present was based on unpublished notes by Dr. S. Kemp. This has been amplified by papers of H. J. Hansen (1905a, 1905b, 1910, 1911) and of G. O. Sars (1885). Numerous papers of Lebour's (1926a, 1926b, 1949) have been useful for the identification of larval stages.

Finally an explanation of the method of calculation of the vertical distribution curves is necessary. For the daytime, a period during the midday from two hours before noon to two hours after noon, has been selected. Previous information on vertical migrations indicates that this period is short enough to exclude any of the rapid changes in the vertical level of the animals such as occur around sunrise and sunset. Thus the noon period selected should find the animals at a fairly constant level. Similarly the night period selected included the period three hours after sunset to three hours before sunrise.

The curves for both day and night periods are derived in the same manner. Values appear at fifty fathom intervals from the surface to 400 fathoms and are corrected to the numbers per mile tow. For each time period the surface hauls are means of surface hauls from all stations. The values at 50, 100, 150 fathoms etc. are means of all hauls within each of the 50 fathoms intervals. Thus the value at 50 fathoms will include all hauls from just below the surface down to 50 fathoms. In cases where the data were insufficient to allow a mean

value to be determined for a day or night period, the totals of all hauls are calculated. Where vertical distribution is based on such totals the fact is referred to in the text.

The list of material upon which this paper is based is too long to be included with the paper and has been deposited with the Director of the Marine Laboratory, University of Miami.

HYDROGRAPHIC CONDITIONS

According to the work of Parr (1933) the water masses present off Miami originated either in the Yucatan Channel or in the Gulf of Mexico. He has given typical temperature-salinity curves for the two masses but has pointed out that when Gulf water is present in the Florida Straits it is usually present as a rather shallow layer and only extends some quarter of the distance across from Miami.

The family of T-S curves from stations SL. 11, 18 are shown in Figure 1 and resemble those of the Yucatan water mass. They fall within the limits of variation observed by Parr for that water mass. There was an observed salinity range of about 35.0 to 37.0‰ which was probably not sufficient to exercise any appreciable biological effect and an observed temperature range of about 9 to 28°C. The mean depth of the 15°C. isotherm was 200 fathoms and of the 10°C. isotherm about 300 fathoms. Although salinity data are lacking for four stations it can reasonably be assumed that all stations were made in water masses which originated in the Yucatan Channel.

LIST OF SPECIES

The following is a list of the species of the Euphausiacea taken in the Florida Straits. Twenty species in all occurred, distributed among five genera.

Thysanopoda tricuspidata Milne-Edwards.

Thysanopoda monacantha Ortmann.

Thysanopoda aequalis H. J. Hansen.

Euphausia americana H. J. Hansen.

Euphausia mutica H. J. Hansen.

Euphausia brevis H. J. Hansen.

Euphausia tenera H. J. Hansen.

Euphausia hemigibba H. J. Hansen.

Euphausia gibboides Ortmann.

Nematoscelis megalops G. O. Sars.

Nematoscelis tenella G. O. Sars.

Nematoscelis microps G. O. Sars.

Nematoscelis atlantica H. J. Hansen.

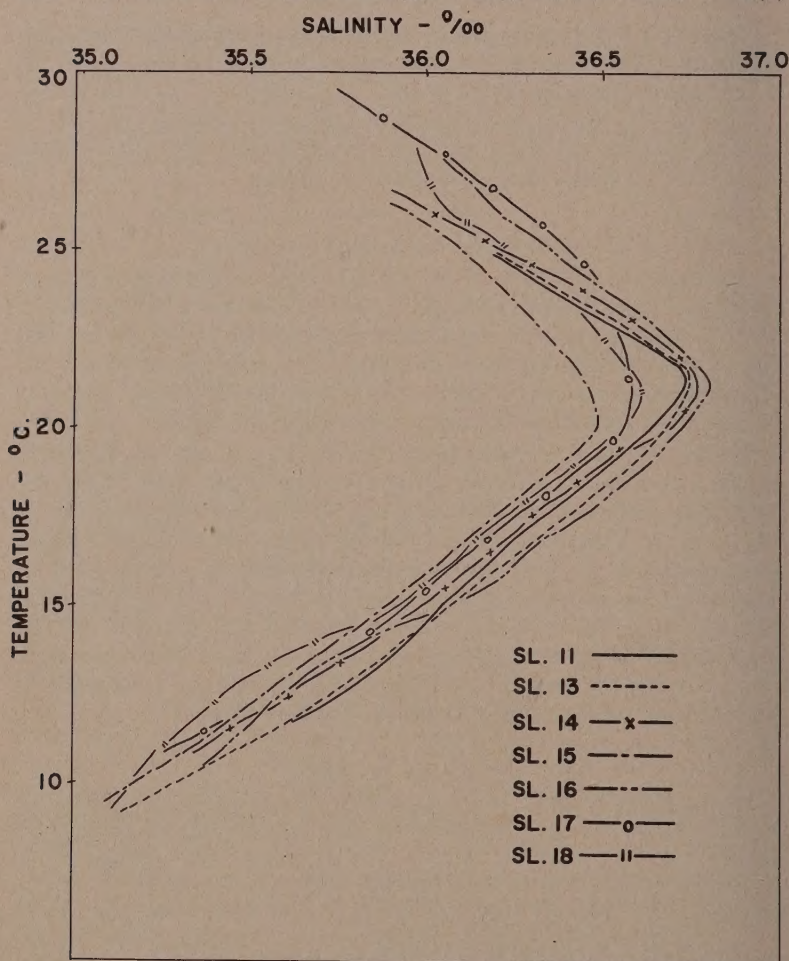


FIGURE 1. Temperature—salinity curves for stations SL. 11-18.

Nematobrachion boopis Calman.
Stylocheiron carinatum G. O. Sars.
Stylocheiron elongatum G. O. Sars.
Stylocheiron longicorne G. O. Sars.
Stylocheiron suhmii G. O. Sars.
Stylocheiron maximum H. J. Hansen.
Stylocheiron abbreviatum G. O. Sars.

OCCURRENCE AND VERTICAL DISTRIBUTION

1. *Thysanopoda tricuspidata* Milne-Edwards.

This species occurred regularly and in small numbers. A total of only seventeen specimens were taken at two stations during the day-time period between 270 and 300 fathoms. Specimens were more abundant in night hauls. The level of maximum abundance was at the surface at night and none was taken below 200 fathoms during that period. The vertical distribution, day and night is shown in Figure 2. Day levels are based on totals from all stations.

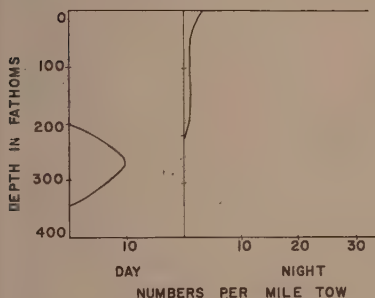


FIGURE 2. *Thysanopoda tricuspidata*. Vertical distribution of adults.

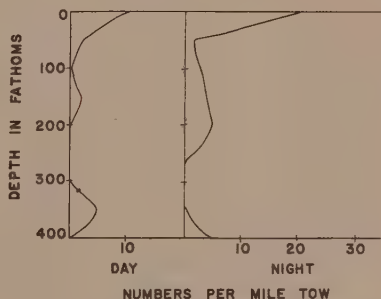


FIGURE 3. *Thysanopoda tricuspidata*. Vertical distribution of calyptopis stages.

Tattersall (1926) gives the level of maximum abundance as between 100 and 200 meters for this species in the Chesapeake Bay to Bahamas portion of the North Atlantic.

The larvae were present in a few hauls from every station and were more abundant than the adults in a number of hauls. A few of the calyptopis stages were found at all depths during both day and night but were most abundant at the surface. The furcilia stages, while present at all depths during the daytime, were absent from the deeper layers at night. There was a fairly heavy incidence of these stages at the surface during the night. The vertical distribution of the larval stages, based on total numbers from all stages is shown in Figures 3 and 4. The larvae have been described by Sars (1885).

From rather few data it appears that diurnal migration in this species is restricted to the adults and furcilia stages. Calyptopis stages apparently remain in the surface layers both day and night.

The numbers are inadequate to define seasonal abundance.

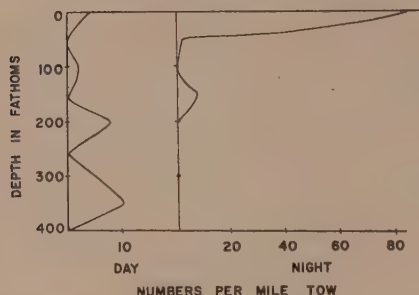


FIGURE 4. *Thysanopoda tricuspidata*. Vertical distribution of furcilia stages.

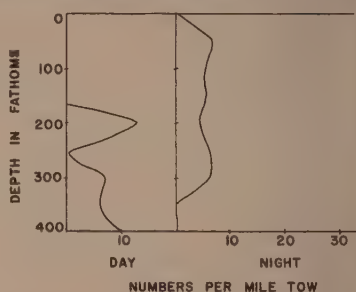


FIGURE 5. *Thysanopoda monacantha*. Vertical distribution of adults.

2. *Thysanopoda monacantha* Ortmann.

This species was taken in small numbers between February and July. It appears to be a deep living form for none was taken above 200 fathoms during the daytime. Figure 5 shows the vertical distribution. From few data it appears that the species moves upwards from the day levels towards the surface at night. None was taken immediately at the surface at night, however.

Tattersall (1926) gives the vertical range of this species between 100 and 200 meters in the Chesapeake Bay to Bahamas area.

No larvae were recognized and the numbers are inadequate to define seasonal abundance.

3. *Thysanopoda aequalis* H. J. Hansen.

This species was taken regularly but in small numbers. The vertical distribution, day and night, is shown in Figure 6. It is a deep living form with a day level of maximum abundance between 250 and 300 fathoms. There is a marked diurnal migration with the night maximum between 50 and 150 fathoms. Only a few specimens were taken at the surface at night.

Tattersall (1926) gives 100-200 meters as the level of maximum abundance of this species from Chesapeake Bay to the Bahamas, Ruud (1936) between 0-200 meters in the Mediterranean, Leavitt (1938) at 800 meters in the Woods Hole region and Moore (1949) below 300 meters during the daytime with a night level of about 50 meters at Bermuda.

This was the most abundantly captured species of the genus. The larval forms which have been described by Lebour (1926a) were en-

countered only occasionally and the numbers are inadequate to define seasonal abundance.

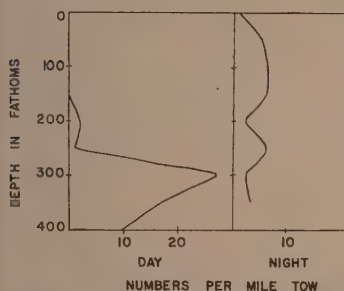


FIGURE 6. *Thysanopoda aequalis*. Vertical distribution of adults.

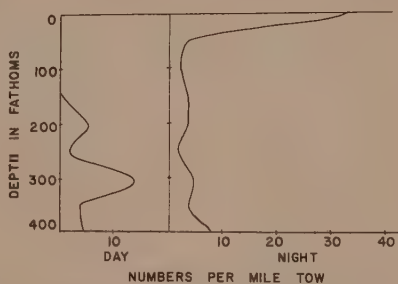


FIGURE 7. *Euphausia americana*. Vertical distribution of adults.

4. *Euphausia americana* H. J. Hansen.

This species occurred fairly regularly but in small numbers. The vertical distribution, both day and night, is shown in Figure 7. It is a deep living species with a daytime level of maximum abundance between 250-300 fathoms. Scarcely any were taken above 150 fathoms during the daytime and diurnal migration is marked with a maximum night level at the surface.

Moore (1949) took this species in small numbers at Bermuda, mostly below 300 meters. Tattersall (1926) gives a maximum level at 0-100 meters from Chesapeake Bay to the Bahamas and Leavitt (1938) above 400 meters near Woods Hole.

The seasonal abundance is shown in Figure 8. Figures for this and other species are based on means of night surface hauls from each

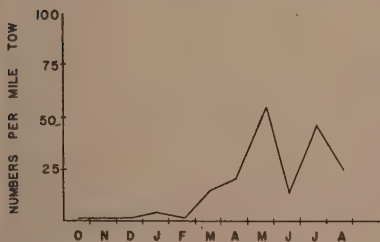


FIGURE 8. *Euphausia americana*. Seasonal abundance of adults.

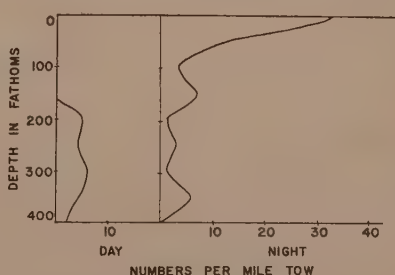


FIGURE 9. *Euphausia brevis*. Vertical distribution of adults.

station. The adults were most abundant during the spring and summer with two peaks, one in May and one in July. The larvae of this species are not known and none was recognized.

5. *Euphausia brevis* H. J. Hansen.

This species was taken regularly at all stations but only in small numbers. It is restricted to depths below 200 fathoms in the daytime. Figure 9 shows the daytime vertical distribution, a fairly uniform one from 200 to 400 fathoms with no marked peak of maximum abundance. The night time distribution shows a pronounced accumulation at the surface and in the upper 50 fathoms.

Moore (1949) found *E. brevis* to be the commonest Euphausiid at Bermuda. He records a day level for the species at 400 meters. It had a diurnal migration up to a level of about 50 meters. Tattersall (1926) gives the maximum at 0-100 meters in the Chesapeake Bay to Bahamas area, Ruud (1936) at 0-200 meters in the Mediterranean and Leavitt (1938) at 200 meters or above in the Woods Hole region.

The larvae of *Euphausia brevis*, both calyptopis and furcilia stages, were fairly common in the hauls. The vertical distribution of the calyptopis stages for both day and night is shown in Figure 10. There is a peak of abundance in the top 50 fathoms both day and night. Only a few larvae were taken below 100 fathoms. There is apparently no diurnal migration, the calyptopis larvae remaining in the surface layers continuously.

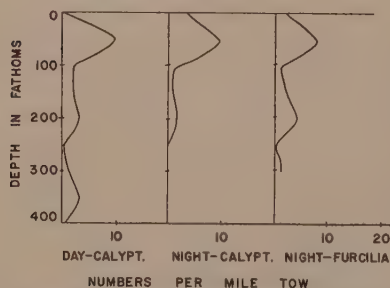


FIGURE 10. *Euphausia brevis*. Vertical distribution of larvae.

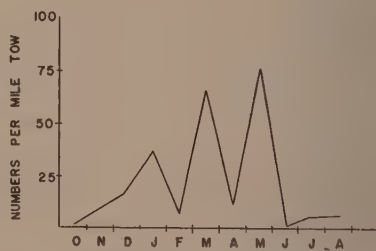


FIGURE 11. *Euphausia brevis*. Seasonal abundance of adults.

The furcilia stages were taken only on a few occasions during the daytime, usually in the shallow layers. Their vertical distribution is shown in Figure 10. Again, the greatest numbers of these stages were found near the surface and although only a few furcilia were taken in

the daytime it appears that there is no vertical migration.

The seasonal abundance of the adults is shown in Figure 11. Early spring appears to be the period of maximum abundance in the area. There are two main peaks, one in March and one in May with a smaller peak in January. The seasonal variation in the numbers of larvae is shown in Table 1. The figures for larvae are based on the main numbers per mile tow in night surface hauls from each station. Both calyptopis and furcilia stages were most abundant during the month of January, two months before the adults appear in large numbers.

The larvae have been described by Lebour (1949) and Gurney (1942).

TABLE 1
THE SEASONAL ABUNDANCE OF *Euphausia brevis*.

Station Number	Calyptopis									
	8	10	11	13	14	15	16	17	18	19
	4	8	32	3	2	0	10	2	9	0
Number Month	Furcilia									
	3	10	36	1	0	0	6	2	3	0
	O	D	J	F	M	A	M	J	J	A

6. *Euphausia mutica* H. J. Hansen.

This species is similar to *E. brevis* in occurrence, vertical distribution and abundance. It has a somewhat wider range in its daytime vertical distribution but at night it moves very definitely towards the surface. During the day it is found in small numbers from 100 fathoms downwards with a slight peak of abundance at 250-300 fathoms. At night the animals are heavily concentrated at the surface. The vertical distribution, both day and night, is shown in Figure 12.

The larvae of *E. mutica* have not been described and none was rec-

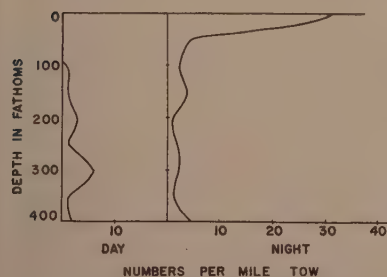


FIGURE 12. *Euphausia mutica*. Vertical distribution of adults.

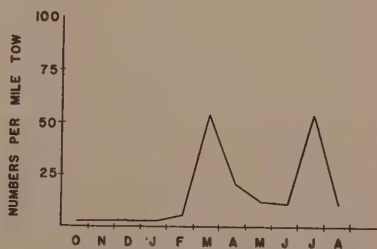


FIGURE 13. *Euphausia mutica*. Seasonal abundance of adults.

ognized. The seasonal distribution of the adults is shown in Figure 13. The distribution is bimodal with peaks of abundance in March and July.

7. *Euphausia tenera* H. J. Hansen.

This was the commonest local Euphausiid. It was rarely captured above 150 fathoms during the daytime and the peak of abundance during this period was between 150 and 200 fathoms. Diurnal migration was marked with the night level of maximum abundance at the surface. Figure 14 shows the vertical distribution by day and by night.

Moore (1949) records *E. tenera* as occurring sporadically at Bermuda, mostly below 300 meters during the daytime with a migration to a level of 50 meters during the night. Tattersall (1926) gives the maximum level at 0-100 meters in the area between Chesapeake Bay and the Bahamas, and Leavitt (1938) above 400 meters in the Woods Hole region.

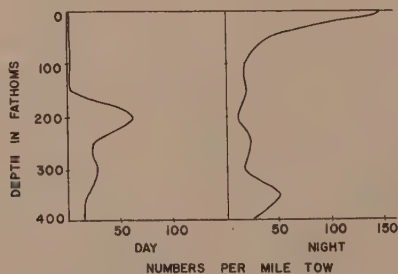
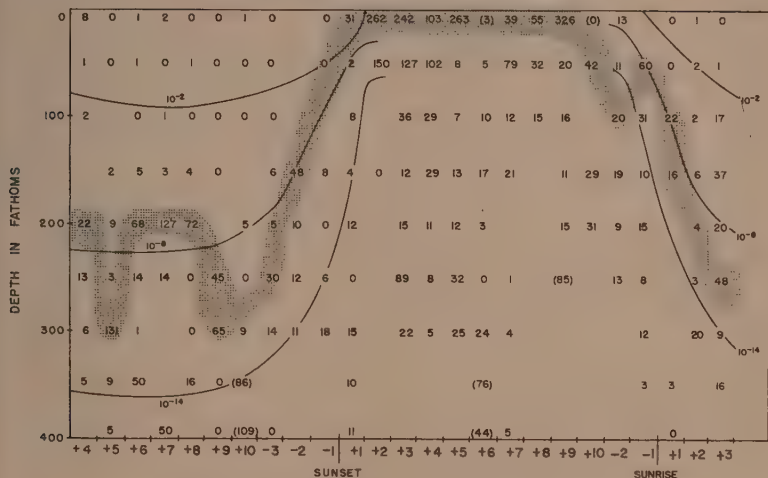


FIGURE 14. *Euphausia tenera*. Vertical distribution of adults.

The pattern of the vertical distribution of this species can be seen from Figure 15. In this figure the full twenty-four hour period has been arbitrarily divided into hourly periods, beginning at sunrise and sunset. The periods before sunrise are designated sunrise -2, -1 etc., while the periods after sunrise are designated sunrise +1, +2 etc. There is a slight overlap because the divisions were begun in two places and hence there are twenty-five divisions instead of twenty-four. The incidence of the species during each hour has been averaged for surface hauls separately and at 50 fathom intervals downwards. Thus each item represents the mean catch for the 50 fathom depth above it. The values have been derived from a half dozen or more hauls. Those which are taken from less than three hauls are in parentheses.

From this Figure it is evident that during the day *E. tenera* occupies

FIGURE 15. *Euphausia tenera*. Diurnal migration.

a level between 150 and 300 fathoms. There are fluctuations at sunrise +4 and at sunrise +10 but the maximum peak of abundance lies close to the one level, 150-200 fathoms. The column sunrise +10 has a maximum at 400 fathoms but this value and the one above at 350 fathoms were based on single hauls and do not warrant the conclusion that the layer of maximum abundance descends to the bottom during this period.

The day level is maintained until about two hours before sunset. During this period the maximum layer begins to ascend, for, at the end of this hour, sunset -2, we find that the peak lies between 100 and 150 fathoms. There were too few data to determine the level of the layer during the next hour but at the end of the first hour after sunset the layer has reached the surface. It thus required about three hours for the level of maximum abundance to move upwards a distance of 200 fathoms from the day level to the surface.

During the evening period the peak of the vertical distribution curve remains at the surface and spreads downwards in considerable numbers as far as 50 fathoms. Only during one hour, sunset +6, is the peak missing from the surface. This is probably due to the fact that again only a single haul for this time was available. The high values at the bottom, at 350 and 400 fathoms are also single readings. The peak begins to move away from the surface again during the period

sunrise -2 and by sunrise $+1$ it has reached a level of about 100 fathoms. By sunrise $+3$ the layer has descended to about 250 fathoms and has regained the day level. Thus the period of morning descent of the maximum layer takes about four hours, a somewhat longer period than the evening ascent.

Superimposed on Figure 15 are three lines, the 10^{-2} , 10^{-8} and 10^{-14} isolumes. These are derived from the means of the same three isolumes for all the stations grouped together. During the daytime the isolume for 10^{-8} illumination passes through the range of the day levels of maximum abundance of *E. tenera*. The level of maximum abundance during the hour sunset -3 is slightly below the isolume but during the rest of the evening ascent, the rate of decreasing light intensity as indicated by the path of the isolumes is closely followed by the ascending animals. Both the path of the 10^{-8} isolume and the path of the ascending animals arrive in the surface layers during the hour immediately following sunset.

The isolumes have been omitted during the night period for reasons of clarity but they remain close to the surface except on nights with a moon. The morning increase in light intensity begins immediately after sunrise and the paths of the isolumes descend in the Figure. Again there is a close correspondence between the path of the 10^{-8} isolume and the path of the descending Euphausiids. Both paths reach approximately the day level of maximum abundance during the hour sunrise $+3$.

The effect of light upon vertical distribution will be more fully analyzed in a later section but it may be noted here how closely the paths of diurnal migration follow the levels of increasing or decreasing light intensity. It is also worthy of note that the light intensity at the depth of the 10^{-8} isolume is comparable with the figures of Clarke (1936). He found that the maximum depth at which a sunfish, *Lepomis*, could see was at 430 meters in the Sargassum Sea where the light intensity at this depth was 10^{-10} times the maximum value of daylight at the surface.

The data for the other species of the genus *Euphausia* were too few to make a similar analysis of the vertical distribution throughout the twenty-four hours. However, for one portion of the day the three species *Euphausia brevis*, *E. mutica* and *E. americana* have been analyzed. These three species are similar in that they have day levels of maximum abundance which are all deeper by about 100 fathoms than the day level of *E. tenera*.

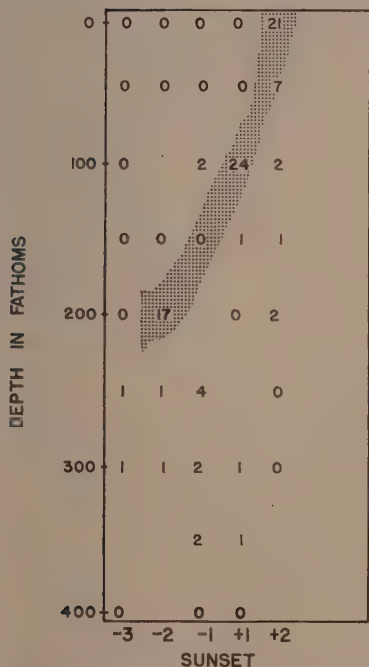


FIGURE 16. *Euphausia brevis*, *E. mu-tica* and *E. americana*. Vertical migration at sunset.

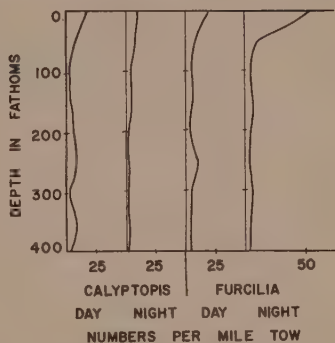


FIGURE 17. *Euphausia tenera*. Vertical distribution of larvae.

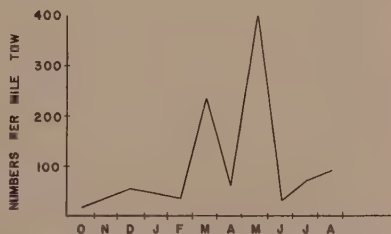


FIGURE 18. *Euphausia tenera*. Seasonal abundance of adults.

Figure 16 shows the vertical distribution of these three species grouped together for the sunset period. The data are few but from the figure it may be observed that during the hour sunset —2, the level of maximum abundance lies between 150 and 200 fathoms, 100 fathoms higher than the level of maximum abundance at midday. At sunset +1 the maximum layer has moved up to between 50 and 100 fathoms and it is not until sunset +2 that the layer reaches the surface. Assuming that the evening ascent begins about the same time as it did for *E. tenera*, sometime during the sunset —2 hour, then it required about four hours for the maximum layer of these species to reach the surface. As might be expected a longer time is required for the deeper dwelling species to reach the surface than for shallower ones and they arrive later.

The larvae of *Euphausia tenera* have been described by Lebour

(1949). They were found regularly at all stations and in total numbers were exceeded only by the larvae of *Stylocheiron carinatum*. The daytime vertical distribution of calyptopis and furcilia stages is shown in Figure 17. This figure shows that the greatest numbers are found at the surface and in the upper layers during the day. Both calyptopis and furcilia were taken as deep as 400 fathoms but only in small numbers.

The night vertical distribution is shown in the same Figure. Both stages are again concentrated at the surface during this period, and, except for this increase in numbers of furcilia stages at night over that for the daytime, the vertical distribution is the same both day and night. There seems to be no evidence of vertical migration of calyptopis stages.

While larvae and adults of this species were taken at all stations, the numbers captured varied considerably. Figure 18 shows the seasonal abundance of the adults. There are two peaks of abundance, one in March and the other in May. The species then, is most abundant in the early spring in these waters.

Table 2 shows the seasonal variation in numbers of larvae. The numbers are based on means of night surface hauls from all stations. There is little variation in the number of calyptopis stages but the furcilia show a marked increase in abundance in May, during the same time as the increase in numbers of adults.

TABLE 2
THE SEASONAL ABUNDANCE OF LARVAE OF *Euphausia tenera*.

Station Number	Calyptopis								
	8	10	11	13	14	15	16	17	18
	9	1	14	8	5	3	14	3	10
Number Month	Furcilia								
	18	1	10	8	10	3	105	18	35
	O	D	J	F	M	A	M	J	J
									23
									A

8. *Euphausia hemigibba* H. J. Hansen.

This species was taken at all stations but in small numbers. The vertical distribution, both day and night is shown in Figure 19. It is the deepest living species of the genus with a day level of maximum abundance between 250 and 350 fathoms. A very few specimens were taken in hauls above 200 fathoms during the daytime. At night the distribution profile is similar to that of the day levels, with a peak of abundance at 250 fathoms. A larger number of specimens were taken above 200 fathoms at night than during the day but only a few at the

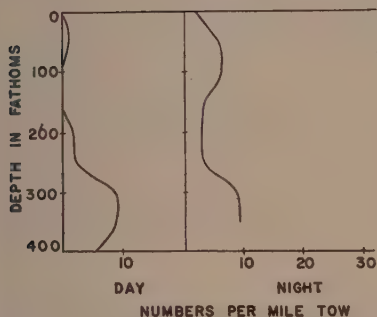


FIGURE 19. *Euphausia hemigibba*. Vertical distribution of adults.

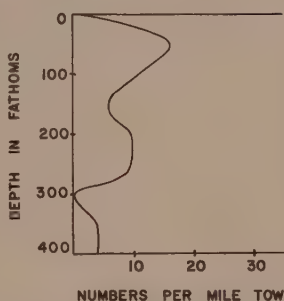


FIGURE 20. *Euphausia gibboides*. Vertical distribution of adults at night.

surface itself. It appears then that there is a slight upward movement in this species during the evening.

No larvae were recognized and the numbers are inadequate to define seasonal abundance.

9. *Euphausia gibboides* Ortmann.

This was the last frequently occurring species of the genus. Only seventeen specimens were taken during the day period; five at 350 fathoms, station 13; five at 166 fathoms, station 19 and seven at 310 fathoms, station 14. The few specimens then were all taken from fairly deep water. There was a higher incidence of specimens in night hauls. Figure 20 shows the vertical distribution of the total number of specimens from all stations taken during the night. None was taken at the surface but the level of the peak of abundance is within the first 50 fathoms.

From such few data it is at least probable that this species undergoes vertical migration towards the surface at night. The data are inadequate to define seasonal abundance.

10. *Nematoscelis megalops* G. O. Sars.

Only a single specimen of this species was captured during the daytime period. It was taken at 270 fathoms at station SL. 8. None was captured at night.

11. *Nematoscelis tenella* G. O. Sars.

This species was more common than *N. megalops*. It appears to be a deep dwelling form because the greatest number were taken between 350 and 400 fathoms. The vertical distribution based on the total

numbers captured for each 50 fathoms is shown in Figure 21. None was taken above 200 fathoms during the day period. The vertical distribution of totals at night is shown in the same figure with the greatest number taken between 100 and 150 fathoms. Although there are few data it appears that this species moves from deep water in the daytime up to about 150 fathoms night level.

A few females of this species were carrying eggs. Apparently breeding takes place in the area sampled although no larvae were recognized.

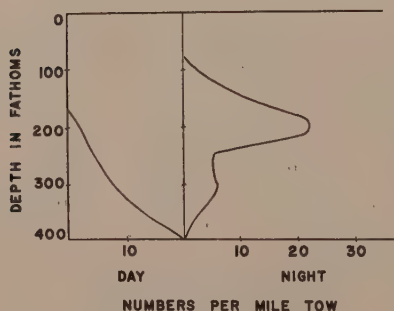


FIGURE 21. *Nematoscelis tenella*.
Vertical distribution of adults.

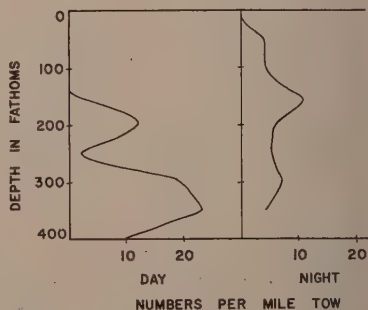


FIGURE 22. *Nematoscelis microps*.
Vertical distribution of adults

12. *Nematoscelis microps* G. O. Sars.

This was the most commonly captured species of the genus. It was taken regularly but in small numbers. It was a deep living form and was not taken above 175 fathoms during the daytime. From the few data available it appears that the level of maximum abundance during the daytime was between 300 and 350 fathoms. The species moves towards the surface at night for at this time they were captured from just below the surface downwards. The night level of maximum abundance was between 100 and 150 fathoms. The vertical distribution, day and night, is shown in Figure 22. Day levels are totals from all stations.

Moore (1949) gives the level of maximum abundance for this species below 300 meters at Bermuda, Tattersall (1926) at 0-200 meters in the Chesapeake Bay to Bahamas area and Leavitt (1938) above 400 meters in the waters off Woods Hole.

The larval stages were taken irregularly and in small numbers. Figures 23 and 24 show the day and night distribution of the larvae. Day

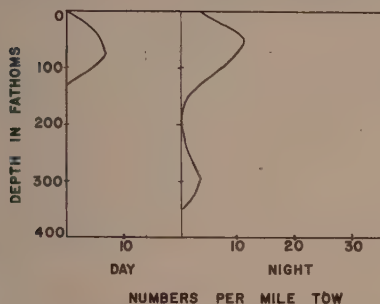


FIGURE 23. *Nematoscelis microps*. Vertical distribution of calyptopis stages.

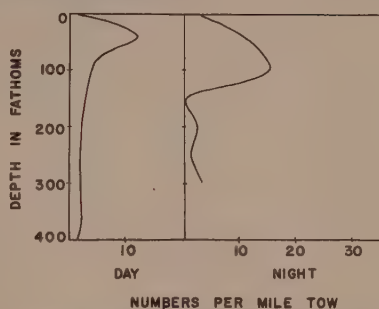


FIGURE 24. *Nematoscelis microps*. Vertical distribution of furcilia stages.

levels are calculated from a single station SL. 15 and night levels are means from three stations SL. 8, 11 and 16. Both calyptopis and furcilia appear to be in maximum abundance at the surface during the day although the furcilia were taken at all depths down as far as 370 fathoms. They were more common in night hauls and both calyptopis and furcilia again show maximum abundance between the surface and 100 fathoms. The larvae have been described by Lebour (1926a). A few ovigerous females were taken at each station.

13. *Nematoscelis atlantica* H. J. Hansen.

Only two specimens of this species were taken during the day period. Both were taken at 270 fathoms at station SL. 8. None was taken in night hauls.

14. *Nematobrachion boopis* Calman.

This is the only species of the genus which was encountered. A few specimens only were taken. During the night period a single specimen was taken at station SL. 11 at 34 fathoms; at station SL. 14, seven at 164 fathoms; at station SL. 15, five at 240 fathoms and at station SL. 18, three at 65 fathoms. None was taken during the daytime period.

15. *Stylocheiron carinatum* G.O. Sars.

This species was exceeded in abundance only by *Euphausia tenera*. It occurred regularly at all stations and often in very large numbers. It is a shallow living species during the daytime. Figure 25 shows the vertical distribution during the day, with a peak of abundance between 50 and 100 fathoms. None was taken at the surface during the daytime but specimens occurred from just below the surface down to 400

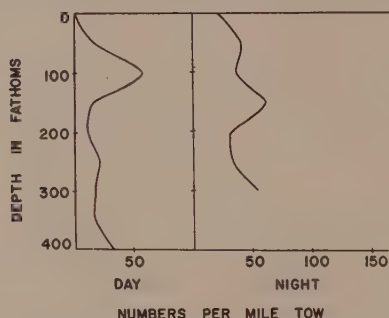


FIGURE 25. *Stylocheiron carinatum*.
Vertical distribution of adults.

fathoms. The vertical distribution at night is shown in the same Figure. The population is fairly evenly distributed throughout the vertical distance from 0-300 fathoms with a slight peak between 100 and 150 fathoms. It appears that there is a slight movement upwards at night from the day level since a larger number of specimens were taken at the surface at night.

Further evidence of diurnal migration in this species can be obtained by comparing the peaks of abundance of day and night periods. Table 3 contains these values for each station. Negative values in the "difference" column indicate an upward movement at night. For each station except one the night peak level is shallower than the day level. The differences vary from 10 to 350 fathoms and a movement towards the surface during the evening was accomplished at all except one station.

TABLE 3
COMPARISON OF THE DAY AND NIGHT PEAKS OF MAXIMUM ABUNDANCE OF
Stylocheiron Carinatum. (ALL DEPTHS IN FATHOMS)

Station	Day Peak	Night Peak	Difference
8	50	40	—10
13	230	100	—130
14	75	140	65
15	350	0	—350
16	60	40	—20
17	350	35	—315
18	160	65	—95
19	220	30	—190

Moore (1949) reports *S. carinatum* as a shallow living form in the Bermuda area with a day level of 95 meters. Tattersall (1926) found

there appears to be a sinking of the population during the night period after the general movement towards the surface has been accomplished in the twilight hours at sunset.

Before the twilight period around sunrise there is another shift in the population. At sunrise -2 and sunrise -1 the peaks of abundance are found in the surface layers, as deep as 50 fathoms and the range of large catches is much smaller than during the earlier part of the night. The surface level is maintained until sunrise $+3$ and during this period the population suddenly shifts down to a level of 250 or slightly below the peak of the day level.

It is apparent that the pattern of vertical migration of this species is very irregular, much more so than is the case with *Euphausia tenera*. The spread of diffuseness of the population is much wider than in *E. tenera* and there is a sinking of the population which did not occur in the latter.

The three isolumes 10^{-2} , 10^{-8} and 10^{-14} have been superimposed on Figure 26. During the daytime the peaks of maximum abundance of *S. carinatum* lie between the limits of the 10^{-2} and 10^{-14} isolumes. As the slopes of the isolumes become steepest during the sunset period the population follows the 10^{-8} isolume fairly closely. During the sunrise period the population lags far behind the descent of the isolumes and the level of maximum abundance during the hour sunrise $+2$ is between the surface and 50 fathoms whilst the 10^{-8} isolume during this hour is between 150 and 200 fathoms. It is not until the next hour when the level of maximum abundance drops very sharply in the figure that the day level and the 10^{-8} isolume reach approximately the same depths.

The larvae of this species were more abundant than the larvae of any other species. The vertical distribution of the calyptopis stages, day and night, is shown in Figure 27. During the daytime the peak of abundance occurs between 50 and 100 fathoms. At night the peak lies between the same levels. There is thus little doubt that diurnal migration does not occur in the calyptopis stages of this species. The vertical distribution of furcilia stages is shown in the same figure. During the daytime the maximum level lies between 50 and 100 fathoms and at night between the surface and 50 fathoms. Only a few furcilia were taken at the surface during the day while during the night they were fairly abundant there. Apparently there is a short vertical shift in the furcilia stages from the day level up towards the surface at night.

Breeding evidently takes place in the Florida area for ovigerous

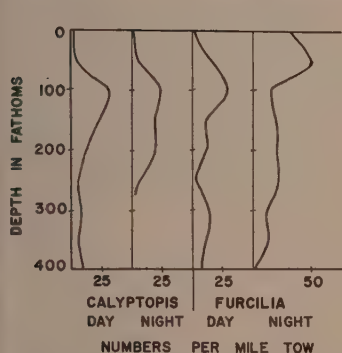


FIGURE 27. *Stylocheiron carinatum*.
Vertical distribution of larvae.

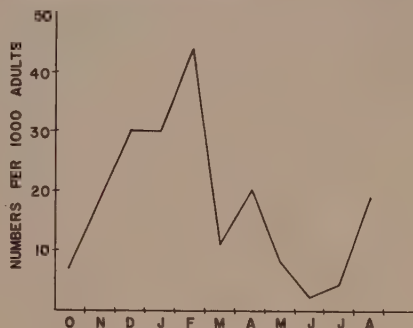


FIGURE 28. *Stylocheiron carinatum*.
Seasonal abundance of ovigerous females.

females were found at all stations. Figure 28 shows the number of egg-bearing females per thousand adults for each station. While some breeding goes on all year round there is a peak of breeding activity during the winter months, especially in February.

The seasonal abundance of the adults is shown in Figure 29. There is a broad peak of abundance during the months of March, April and May, followed by a low period and another rise in numbers in the late summer in August. The spring increase in numbers thus comes shortly after the breeding period during the winter.

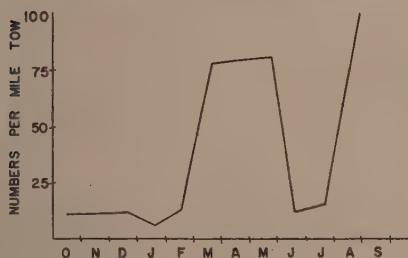


FIGURE 29. *Stylocheiron carinatum*.
Seasonal abundance of adults.

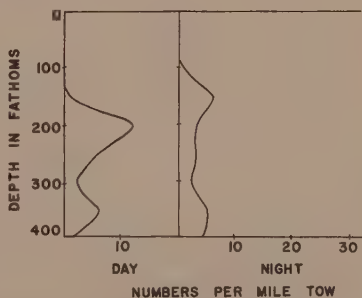


FIGURE 30. *Stylocheiron elongatum*.
Vertical distribution of adults.

Of the larvae, the calyptopis stages were not present in sufficient numbers to adequately define their seasonal variation. However, their variation, based on night hauls over the whole depth range and the

seasonal variation of the furcilia stages are contained in Table 4. The furcilia stages show much the same sort of distribution as do the adults, increased numbers in the spring and again in the late summer. They were most abundant in February—a month before the high incidence of the adults—and were present in large numbers until May. There is a second weaker peak of abundance in July and August.

The larvae of this species have been described by Hansen (1912) and by Lewis (in press).

TABLE 4
SEASONAL ABUNDANCE OF THE LARVAE OF *Stylocheiron carinatum*.

Station Number	Calyptopis									
	8	10	11	13	14	15	16	17	18	19
	1	1	2	2	12	11	3	3	3	1
Number Month	Furcilia									
	1	1	12	40	33	27	19	3	29	29
	O	D	J.	F	M	A	M	J	J	A

16. *Stylocheiron elongatum* G. O. Sars.

This was a comparatively scarce species in the area studied. The vertical distribution, day and night, is shown in Figure 30. During the daytime it was not taken above 150 fathoms, the peak of abundance was between 150 and 200 fathoms and it was found all the way down to 400 fathoms. At night there was a fairly even distribution from about 100 fathoms down to the bottom. None were taken at the surface at night and there was no apparent vertical migration.

Moore (1949) records this species mostly at 250-300 meters or below at Bermuda, Tattersall (1926) gives the maximum level at below 300 meters in the Mediterranean.

The larvae were captured only occasionally and in small numbers. They have been described by Lewis (in press). The numbers are inadequate to define seasonal abundance.

17. *Stylocheiron longicorne* G. O. Sars.

This species occurred regularly but in small numbers. The vertical distribution is shown in Figure 31. It was not taken above 100 fathoms during the daytime and occurred from this depth almost to 400 fathoms. The vertical distribution at night was similar to that of the day period with none taken over 100 fathoms and no evidence of vertical migration.

Moore (1949) gives the day level in the Bermuda area at 195 meters, Tattersall (1926) as below 200 meters in the Chesapeake Bay

to Bahamas area, Ruud (1936) from 0-200 meters in the Mediterranean and Leavitt (1938) as 200 meters or less. Moore found evidence of a short vertical migration for this species at Bermuda.

The larvae which have been described by Frost (1935) were encountered occasionally at shallow depths. The numbers are inadequate to define seasonal abundance.

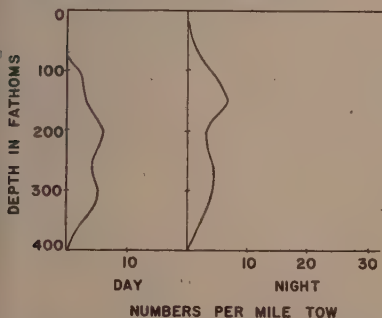


FIGURE 31. *Stylocheiron longicorne*.
Vertical distribution of adults.

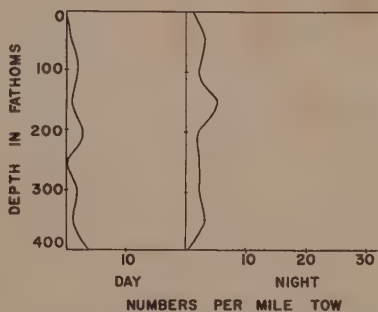


FIGURE 32. *Stylocheiron suhmii*.
Vertical distribution of adults.

18. *Stylocheiron suhmii* G. O. Sars.

This species occurred regularly but in small numbers. None was taken at the surface during the daytime but the species was fairly evenly distributed from 50 fathoms down to 400 during this period. At night the vertical distribution was again rather even from the surface to 400 fathoms. There is thus no evidence of vertical migration. The vertical distribution for day and night is shown in Figure 32.

Moore (1949) has recorded this as a shallow living species in the Bermuda area with a mean day level at 95 meters. Ruud (1936) gives the day level at 0-200 meters in the Mediterranean and Tattersall (1926) at 100-200 meters in the area between Chesapeake Bay and the Bahamas.

The larvae occurred occasionally at all depths. They have been described by Lebour (1926a, 1926b). The numbers are inadequate to define seasonal abundance.

19. *Stylocheiron maximum* H. J. Hansen.

Only four adult specimens of this species were taken at 140 fathoms during the night period. None was taken during the day. Moore (1949) records a few specimens at Bermuda, Tattersall (1926) gives the day level at below 200 meters in the Atlantic between Chesapeake

Bay and the Bahamas and Ruud (1936) below 300 meters in the Mediterranean.

20. *Stylocheiron abbreviatum* G. O. Sars.

Only a few adult specimens of this species were taken. They were captured from the surface down to about 350 fathoms both day and night. Moore (1949) records this species in small numbers with a day level at 105 meters at Bermuda and has found evidence of vertical migration. Tattersall (1926) gives the day level below 200 meters between Chesapeake Bay and the Bahamas and Ruud (1936) finds it below 300 fathoms in the Mediterranean.

The larvae occurred in small numbers, mostly in the shallow layers. They have been described by Lebour (1926b) and by Lewis (in press).

THE ENVIRONMENTAL FACTORS AFFECTING VERTICLE
DISTRIBUTION.

The following terms are employed in describing the ecology of the group:

50% level. The depth above which one half of the individuals occurring in the whole column from the surface to 400 fathoms are found. It is not a level of concentration of numbers but rather a measure of diffuseness away from the surface.

Day level of maximum abundance. The level at which the heaviest concentration of individuals is found during the day. Statistically it is the mode of a vertical distribution curve.

Upper deviation level. The depth above which one half of the individuals occurring in the column from the surface to the day level of maximum abundance are found.

Lower deviation level. The depth above which one half of the individuals occurring in the column from the day level of maximum abundance down to 400 fathoms are found.

Spread. The distance between the day level of maximum abundance and the upper or lower deviation levels. It is a measure of the diffuseness of the population about the day level of maximum abundance.

As a preliminary to the discovery of the factors which influence the daytime vertical distribution of the Euphausiacea, the effect of light and temperature on the depth of the 50% day level have been tested. The net hauls and data for the four hour noon period have been select-

ed for reasons previously outlined. It was found that for all species grouped together there was a positive and significant correlation between the depth of the 50% level and the depth of the 10^{-8} isolume at noon. The coefficient of correlation was +0.44 and it was significant at the 5% level. The correlation of the depth of the 15°C. isotherm with depth of the 50% level was found to be not significant. Since the 50% level is a measure of the diffuseness of the population, the change in its level can be interpreted as an increase or decrease in the spread of the population from the surface. It appears that this diffuseness is influenced by illumination but not by temperature.

Applying the same methods to the two most abundantly occurring genera, *Euphausia* and *Stylocheiron*, it was found that there was a positive and significant correlation of depth of the 50% level and depth of 10^{-8} isolume for the genus *Euphausia*. A similar correlation for the genus *Stylocheiron* yielded a correlation coefficient which was positive but not significant.

For further analysis of the effects of light and temperature on vertical distribution use has been made of the concept of a day level of greatest concentration, i.e., the day level of maximum abundance. Since the preliminary analysis of the pattern of vertical movement has indicated slight differences in the behaviour of at least two species of different genera, *Euphausia tenera* and *Stylocheiron carinatum*, the two genera have been treated separately wherever possible. Where the data was insufficient for the application of a statistical technique, the two groups have been treated together.

The effect of light on the day levels of maximum abundance was studied first. Correlations of the day levels of maximum abundance with the depths of the 10^{-8} isolume at noon for the genus *Euphausia* and with the 10^{-2} isolume for the genus *Stylocheiron* were tested. Similarly the relation between the depths of the day levels of maximum abundance and the depths of the 15°C. isotherm were tested. The results are shown in Table 5.

TABLE 5
CORRELATIONS OF ISOTHERM AND ISOLUME WITH DAY LEVELS OF MAXIMUM ABUNDANCE.

Genus	Coefficient of Correlation	
	Isolume	Isotherm
<i>Euphausia</i>	+0.579	-0.398
<i>Stylocheiron</i>	+0.204	+0.046

Only one of the correlation coefficients of Table 5 was found to be

significant, that of the correlation of day level of the genus *Euphausia* with the depth of the 10^{-8} isolume at noon. The coefficient was significant at the 1% level. No significant correlation of isolume with day level of maximum abundance for the genus *Stylocheiron* could be found and the correlation coefficients of temperature with day level was found to be significant for both genera. Thus the day levels of maximum abundance of the genus *Euphausia* were under the control of light. The deeper the light penetrated during the day the deeper were the day levels of the animals. Since the day level of maximum abundance represents the depth at which the animals are concentrated during the day, it appears that there is an optimum light intensity for the genus.

Further information on the influence of light on vertical distribution during the daytime can be gained by studying the vertical diffuseness or spread of the population. Two other population parameters, the upper and lower deviation levels, have been selected as arbitrary limits to the vertical diffuseness on either side of the day level of maximum abundance. Taking all the species together into consideration it was found that there was a positive and significant correlation between the depths of the day level of maximum abundance and the upper deviation level. This simply means that as the day level of maximum abundance moves deeper the upper deviation level moves deeper also. However, it was also found that there was a positive and significant correlation between the upper spread and the day level of maximum abundance. Thus the upper spread of the population increases as the day level of maximum abundance moves deeper. This can be interpreted as meaning that the deeper the population is on any one day the more diffuse the upper portions of the population. Also in terms of the upper deviation level itself, it follows that this level moves up and down more slowly than does the day level of maximum abundance.

The influence of physical factors on the upper spread can be studied by holding the depth of the day level of maximum abundance constant and testing the effect of light and temperature on the upper deviation level. By the statistical method of partial correlations, eliminating the effect of the movement of the day level of maximum abundance, it was found that there was a positive and significant correlation between the upper deviation levels of all species grouped together and the depth of the 10^{-8} isolume at noon. Similar treatment of the depth of the 15°C . isotherm and the depth of the upper deviation level yielded

a correlation coefficient that was not significant. Thus the upper deviation level is under the control of light. The various coefficients of correlation between the upper deviation levels and temperature and light are contained in Table 6.

TABLE 6

Species	Correlation	Coefficient	Significance
All combined	Upper deviation level and day maximum	+0.460	at 5%
All combined	Upper spread and day maximum	+0.750	at 1%
All combined	Upper deviation level and 10 ⁻⁸ isolume (partial)	+0.510	at 1%
All combined	Upper deviation level and 15°C. isotherm (partial)	-0.022	not significant

The same techniques have been applied to the lower deviation levels and the spread of the lower part of the population below the day level of maximum abundance. The results appear in Table 7. The lower deviation level moves up and down with the day level of maximum abundance as did the upper level. However, there was a negative and significant correlation between the lower spread and the depth of the day level of maximum abundance. This means that while the day level and the lower deviation level may both move deeper, the rates of movement are not the same and the deeper the population moves as a whole, the less the spread at lower levels.

TABLE 7
CORRELATION OF LOWER DEVIATION LEVELS WITH TEMPERATURE AND LIGHT.

Species	Correlation	Coefficient	Significance
All combined	Lower deviation level and day maximum	+0.901	at 1%
All combined	Lower spread and day maximum	-0.507	at 5%
All combined	Lower deviation level and 15°C. isotherm (partial)	-0.120	not significant
All combined	Lower deviation level and 10 ⁻⁸ isolume (partial)	+0.07	not significant
All combined	Lower spread and 15°C. isolume (partial)	+0.138	not significant

By holding the depth of the day level of maximum abundance constant, no control of the lower deviation level by light could be found. No direct correlation could be found between the depth of the lower deviation level and the depth of the 10 or 15°C. isotherms but by

testing the correlation of the variation of the lower spread and the distance of the 10°C. isotherm from the day level of maximum abundance, a positive and significant correlation was obtained (+0.415 at the 5% level). This means that the further the 10°C. isotherm is from the day level of maximum abundance the more diffuse the population at lower levels and the deeper portion of the population appears to be limited in its downward movement by low temperatures.

The influence of light and temperature on vertical distribution at night has been investigated in much the same manner as for the day-time distribution. The time period, three hours after sunset to three hours before sunrise, has been selected for study for reasons previously given. For the two genera *Euphausia* and *Stylocheiron*, treated separately, it was found that there was a positive and significant correlation between the 50% night level and the depth of the 10⁻⁸ isolume at midnight. The correlation coefficients are shown in Table 8.

TABLE 8
CORRELATION OF 50% LEVEL AT NIGHT AND DEPTH OF 10⁻⁸ ISOLUME.

Genus	Correlation	Coefficient	Significance
<i>Stylocheiron</i>	50% level and 10 ⁻⁸ isolume	+0.453	at 5%
<i>Euphausia</i>	50% level and 10 ⁻⁸ isolume	+0.478	at 5%

In the case of the genus *Euphausia*, the night levels of maximum abundance are very close to the surface (see Figures 7, 9, 12 and 14) while in *Stylocheiron carinatum* there was a downward movement during part of the night although for most of the night the population was in the shallow layers. Because of these shallow concentrations it has not been possible to test the influence of light on levels of maximum abundance nor on upper deviation levels as was done with the daytime distribution. No significant correlation between temperature and night levels, expressed as vertical diffuseness, could be found. For the genus *Euphausia*, the population is so concentrated in the surface layers that it was probably above the influence of low temperature. *Stylocheiron* species were found in deeper water during part of the night but no correlation of lower deviation level with isotherm could be discovered. Illumination thus appears to be the only one of the two factors which influence vertical distribution at night.

DISCUSSION

In general, the day levels of the species of Euphausiacea here recorded from the Florida Current are lower than has been reported by

other authors. The vertical distribution of the Euphausiacea in the Atlantic and in the Mediterranean is shown in Table 9. Only *Thysanopoda aequalis* which was found at 800 meters by Leavitt (1938) was taken in shallower water at 450-550 meters in the Florida area. The species of the genus *Stylocheiron* show the least differences in day levels between the various areas.

In view of the dual control of light and temperature over vertical distribution recognized here and emphasized by Moore et al (1953) it is interesting to compare the differences in these two factors between the various areas which have been covered in the investigations of Moore (1949), Tattersall (1926), Ruud (1936) and Leavitt (1935). Ruud (1936) has pointed out that the Euphausid day levels recorded in the Atlantic by Tattersall were lower than those in the Mediterranean because of the higher temperatures which are found in the Atlantic area. Moore (1950) has shown that the scattering layer is on the whole shallower in the Mediterranean than at the Azores and that the temperatures at the depth of the layer in the latter region are much higher than in the Mediterranean. Further he found that the greater depth of the layer at the Azores was in agreement with the higher illumination there. Moore (1952) has charted the distribution of temperature at the depth of the 10^{-12} isolume in summer in the Atlantic. The temperature which lies at this depth in the Florida Straits is 17, in the Eastern Atlantic off the Bay of Biscay between 10 and 11, in the Western Atlantic within the line of the Gulf Stream it is less than 10 and in the Mediterranean it is between 13 and 14°C. That the temperatures are higher in the Florida Straits than in the other areas with which we are concerned can also be seen from charts published by Hela et al (1953) and by Sverdrup et al (1942). It is thus apparent that the high temperatures in the Florida area allows the deeper penetration of the Euphausids during the daytime.

The distribution of extinction coefficients in the Atlantic and Mediterranean has been plotted by Moore (1952). Extinction coefficients in the Florida Straits vary over a wide range between 0.06 and 0.10 with the lowest values on the Bahamas side of the Straits in the area of our stations. These low values of Moore's are comparable with the values recorded in the Gulf Stream and Sargassum Sea by Clarke (1936). The values in the Mediterranean are about as high or slightly higher than those for the Florida Straits and the coefficients plotted by Moore for the Chesapeake Bay and Woods Hole areas are considerably higher than both the Mediterranean and Florida waters.

TABLE 9
THE VERTICAL DISTRIBUTION OF THE EUPHAUSIACEA IN THE NORTH ATLANTIC AND MEDITERRANEAN.

Species	Florida	Bermuda (Moore)	Day levels in meters		Atlantic (Tattersall)	Atlantic (Leavitt)
			Medit. (Ruud)			
<i>Thys. aequalis</i>	450-550	below 300	0-200	100-200		800
<i>E. americana</i>	450-550	below 300		0-100		
<i>E. brevis</i>	below 370	400	0-200	0-100		
<i>E. tenera</i>	275-375	below 300		0-100		above 400
<i>E. mutica</i>	450-550			0-100		
<i>E. hemigibba</i>	450-650	below 400	0-200	0-100		above 400
<i>N. microps</i>	550-650	below 300	0-200	100-200		below 400
<i>S. carinatum</i>	100-200	95	0-200	100-200		above 400
<i>S. submii</i>	below 100	95	0-200	100-200		
<i>S. longicorne</i>	below 200	195	0-200	below 200		above 200
<i>S. elongatum</i>	275-375	below 250	below 300	200		

The coefficient of extinction is not however the only criterion of the intensity of illumination at a given depth. Unfortunately there does not appear to be any published data on the geographical distribution of absolute illumination values but Moore (1952) has shown that the illumination at the depth of the 16°C. isotherm is greater in the vicinity of the Florida Straits than elsewhere in the Atlantic. Thus both factors, temperature and illumination, are acting to allow the deeper penetration of the Euphausids in the Florida area.

Vertical migrations have been shown for certain in adults of the following species: *Thysanopoda aequalis*, *Euphausia americana*, *E. brevis*, *E. mutica*, *E. tenera*, *Nematoscelis microps* and *Stylocheiron carinatum*. It is less certain in *Thysanopoda tricuspidata*, *T. monacantha*, *Euphausia gibboides*, *E. hemigibba* and *Nematoscelis tenella*. There was no apparent evidence for diurnal migration in *Stylocheiron elongatum*, *S. longicorne* or *S. suhmii* although evidence for such migration was found for the latter three species by Moore (1949) in the Bermuda area. In the species of the genus *Euphausia* there was a marked concentration of the animals at the surface throughout the whole period of the night. On the other hand, *Stylocheiron carinatum* showed a tendency to move downwards during part of the night and towards the surface again before dawn.

There was no evidence of vertical migration in the calyptopis stages of any of the species analyzed. The calyptopis stages of *Thysanopoda tricuspidata*, *Euphausia brevis* and *Euphausia tenera* were most abundant at the surface both day and night. The same stages of *Stylocheiron carinatum* were most abundant between 50 and 100 fathoms both day and night and of *Nematoscelis microps* between the surface and 50 fathoms. There appeared to be short vertical migrations of the furcilia stages of *Thysanopoda tricuspidata*, *Euphausia tenera* and *Stylocheiron carinatum*. In these three species there was a higher incidence of larvae in night surface hauls than in day surface hauls.

Only five species of adult Euphausids, *Euphausia americana*, *E. tenera*, *E. brevis*, *E. mutica* and *Stylocheiron carinatum*, were present in adequate numbers to allow definition of their seasonal abundance. It was evident that the peaks of abundance occurred in the spring and early summer in all species. Such seasonal variation could be due to breeding cycles and the maturation of the young during the spring or it could be due to a sudden influx of numbers from another area. Of the first possibility it may be said that since very young larvae of a number of species were present we may infer the breeding of those

species in the area. Furthermore, ovigerous females of *Stylocheiron carinatum* and *Nematoscelis microps* were observed throughout the year. There was a peak of abundance of ovigerous females of *S. carinatum* in February, preceding the peak of abundance of furcilia larvae in February and March. The highest incidence of adults occurred from March through May, following the larval peak. The adults of *Euphausia tenera* were most abundant in March and May while the peak of abundance of larvae was in May. The larvae of *Euphausia brevis* were most abundant in January, two months before the adults appeared in large numbers. Thus there is some indication that the local seasonal abundance of adults follows a spawning period in *Stylocheiron carinatum* and *Euphausia brevis*.

In regards the second possibility, an influx of adults from outside, it may be pointed out that all the water passing through the area comes originally from another area. Immediately it comes from the Yucatan Channel and the eastern part of the Caribbean but further in the past it was a mixture of Atlantic waters. Because of the heavy mixing that occurs in the Caribbean these waters lose their water mass characteristics and it is difficult to detect traces of their origin. Without further knowledge of the fauna of the Atlantic waters where they enter the Caribbean it is impossible to do more than state the possibility of this reason for the seasonal fluctuations of adult Euphausiacea in the Florida Current.

SUMMARY

1. The vertical distributions of twenty species of adult and five species of larval Euphausiids are described. There is evidence of diurnal migrations in the adults of twelve species and in the furcilia larvae of three species. There is no evidence of diurnal migrations in the calyptopis larvae.
2. The vertical distribution of the adults during the day is shown to be under the control of light and temperature. Light influences the upper portions of the population and the day levels of maximum abundance while low temperature limits the deep penetration of the animals. The vertical distribution at night is shown to be under the control of light. During the dawn and dusk periods the paths of descending and ascending concentrations of two species follow closely the lines of increasing and decreasing illumination values.
3. The importance of light and temperature upon geographical var-

iation of vertical distributions is demonstrated and the relatively deep day level of the group in the Florida Straits is shown to be a result of the comparatively deep penetration of light and the high temperatures in the area.

4. The adults of the five most abundant species were most common in the spring and summer. Whether such increases in numbers are due to breeding cycles or to an influx of numbers from another area is not known.

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A PRELIMINARY REPORT ON THE SPAWNING OF THE WESTERN NORTH ATLANTIC BLUEFIN TUNA (*THUNNUS THYNNUS*) IN THE STRAITS OF FLORIDA¹

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ABSTRACT

Evidence indicating that the western north Atlantic bluefin tuna spawns in the Straits of Florida during May and early June is presented. Such evidence includes the occurrence of ripe and recently spawned adult fish simultaneously with what may be fertilized eggs and larvae. Further evidence includes the occurrence of juveniles and young in the vicinity of the spawning grounds. It is inferred that the large, adult fish spawning in the Straits of Florida are the same which are found in northern waters during summer. The discovery of spawning grounds in the western Atlantic also suggests that the American and European bluefin tuna represent separate, independent units.

INTRODUCTION

Although the spawning grounds and season of the eastern north Atlantic (European) population of the bluefin tuna (*Thunnus thynnus*) have been known for the Mediterranean for more than thirty years (Roule, 1924; Ehrenbaum, 1924; Sanzo, 1929; de Buen, 1937; Frade, 1937), those of the western Atlantic representatives had remained hitherto undiscovered.

Through a research fellowship made available to the University of Miami Marine Laboratory by the Charles F. Johnson Foundation, Inc., a study of the life history of the western north Atlantic bluefin tuna was begun in 1952 as the "Western North Atlantic Bluefin Tuna Cooperative Research Program" (Rivas, 1952). Among other phases of the project, the discovery of the spawning grounds and determination of the breeding season were given considerable attention, and although much remains to be done, it is believed that the results so far obtained justify the presentation of a preliminary report.

In addition to the Charles F. Johnson Foundation, the cooperation of the management of the Cat Key Club, Bahamas, and of the officers and anglers participating in the eighth, ninth and tenth Cat Cay In-

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Mr. Benjamin Garcia made available the use of his cruiser *Dona Rosa II* for the collection of plankton material off the north coast of Havana, Cuba, during April and May, 1953, and Al Pflueger and Captain Eddie Moore of Miami, Florida, loaned their boats *Gunner II* and *Panda* respectively, for the period of work at Cat Cay and Bimini, Bahamas, during May and June, 1953. Dr. Charles E. Lane, Gilbert Voss, George Arata and Donald de Sylva, all of the University of Miami Marine Laboratory, assisted with the collection of data in Cat Cay and Bimini. The author's wife, Orosia C. Rivas assisted during the period of work at Bimini in 1952.

EVIDENCE TOWARDS LOCATION OF SPAWNING GROUNDS AND DETERMINATION OF SEASON

The known European bluefin tuna spawning grounds comprise mainly the central Mediterranean (Roule, 1924) and the breeding season extends from late April through about the middle of July (Roule, 1924; Heldt, 1926; Sanzo, 1929). The ripening of the gonads begins about late April and early May in various parts of the Mediterranean (Roule, 1924). At this time, the fish school in great numbers and form shoals composed sometimes of several thousand individuals which then travel to the spawning grounds where they arrive during the last two weeks in May. Sexual maturation is then completed and the actual spawning takes place during the months of June and early July.

Fernando de Buen, quoted by Heldt (1926), offers the following frequency distribution of gonad development for bluefin tuna from the southwestern coast of Spain for the year 1923.

	MAY	Males	Females
Not yet ripe		100%	100%
	JUNE		
Not yet ripe		32%	67%
In full maturity		60%	30%
Spent		8%	3%
	JULY		
Not yet ripe		1%	26%
In full maturity		33%	12%
Spent		66%	62%
	AUGUST		
Spent		100%	100%

The above frequency indicates that actual spawning takes place during June and July in southwestern Spain and confirms Roule's observations for the Mediterranean. The occurrence of eggs in the strait of Messina as determined by daily plankton tows conducted during the months of May, June and July of the years 1925, 1926, and 1927 (Sanzo, 1932), also indicates that spawning takes place from late May through the middle of July.

As to environmental factors affecting spawning of the European bluefin tuna, Roule (1924) states that the breeding fish seek the warmer and most saline waters. Heldt (1932) presents evidence that spawning may take place either in shallow or deep water but close to the surface at depths of about 8 or 10 meters.

In regard to the western north Atlantic bluefin tuna, Sella (1931) suggests that its spawning grounds should not be looked for in Canadian waters. His deductions, as pointed out by Heldt (1931) are based on certain ecological analogies existing between the American and European bluefin tunas. Since migration after spawning is effected in Europe from the south towards the north, Sella concludes that in American waters, the spawning grounds should be located in the south. Heldt (1931), suggests that according to the time of the year (late June to early July) when the bluefin tuna appear off the coasts of New England and Canada, the spawning season of the American bluefin tuna must be the same as that of the Mediterranean fish.

According to Westman and Neville (1942:24): "The indications are that the [American] Atlantic bluefin is a winter or an early spring spawner. Such evidence includes the apparent absence of ripe fish during the summer and fall months . . ." More recently Mowbray (1949:201), quotes a statement from the American Museum of Natural History as follows: "There is really no data on where our [American] Bluefins go in fall or where they spawn. Just as a guess, when the tuna leave Nova Scotia waters, all full of herring, they head well to the east, working directly or indirectly towards an unknown spawning ground, perhaps in the Caribbean or Gulf. It is probably an area with particularly high water temperatures in the fall. Oceanographers might be able to give some clue to its location. They probably spawn in fall, if the young, a foot or little more long, which are not rare hereabouts in late summer, are less than a year old, as supposed." He then suggests that the European and the American bluefin tuna ". . . have a common spawning ground in the vicinity of fifteen degrees North Latitude, and between thirty and forty degrees West

Longitude." As to season, Mowbray (loc. cit.) is of the opinion that the fish "... spawn about February or March, or even as late as April."

OCCURRENCE OF BLUEFIN TUNA IN THE STRAITS OF FLORIDA

The periodic occurrence of bluefin tuna along the Bahama side of the Florida Straits (Rivas, 1951, 1952) was discovered in 1933 by fishing guides and anglers operating out of Miami, Florida, and Cat Cay, Bahamas. (See also Farrington, 1949a: 170, 171).

Every year, about the middle of May, bluefin tuna appear in large numbers on the shallow edge of the Great Bahama Bank in the vicinity of Riding Rocks and Orange Cay (Figure 1), moving in from deep water apparently along the edge of the Florida Current in a northeasterly direction. Upon reaching shallow water, the fish turn to a northerly course and follow the edge of the bank close to Cat Cay, the Bimini Islands, Great Isaac, Grand Bahama Island, and leave the Little Bahama Bank in the vicinity of Manzanilla Shoal still traveling in a northerly direction. Intensive aerial and surface observations conducted by anglers during a period of about 7 years and by the writer during 1951, 1952 and 1953, have failed to reveal the presence of bluefin tuna along the western edge of the Bahama Bank, south of Orange Cay. The fish movements continue during the rest of May and early June, very few fish being seen after the fifteenth and none towards the end of the month. Although the bulk of the migration begins about the middle of May, a few scattered individuals and small schools are seen moving north along the same path as early as late April. A fish weighing 316 pounds was caught off Bimini on April 24, 1952, and a small, isolated school composed of 4 individuals was seen by the writer on the same day from a Coast Guard plane, close to and west of Orange Cay. The first bluefin tuna of the 1953 season, a few isolated individuals, were seen on April 25. Aerial and surface observations were conducted during 1952 and 1953 before the expected time of arrival of the fish, in order to ascertain this period with greater accuracy. (See also Farrington, 1949a: 170).

Only large, adult individuals ranging from about 300 to about 700, usually 400 to 500 pounds in weight (Table 1), are involved in this migration. It may be pointed out here that the size of hook (9/0 to 14/0, usually 10/0 or 11/0) used by anglers in the Bahamas, is not selective for the size of individuals. The same sizes are used at Wedgeport, Nova Scotia (Farrington, 1949b: 8, 233, 278) where

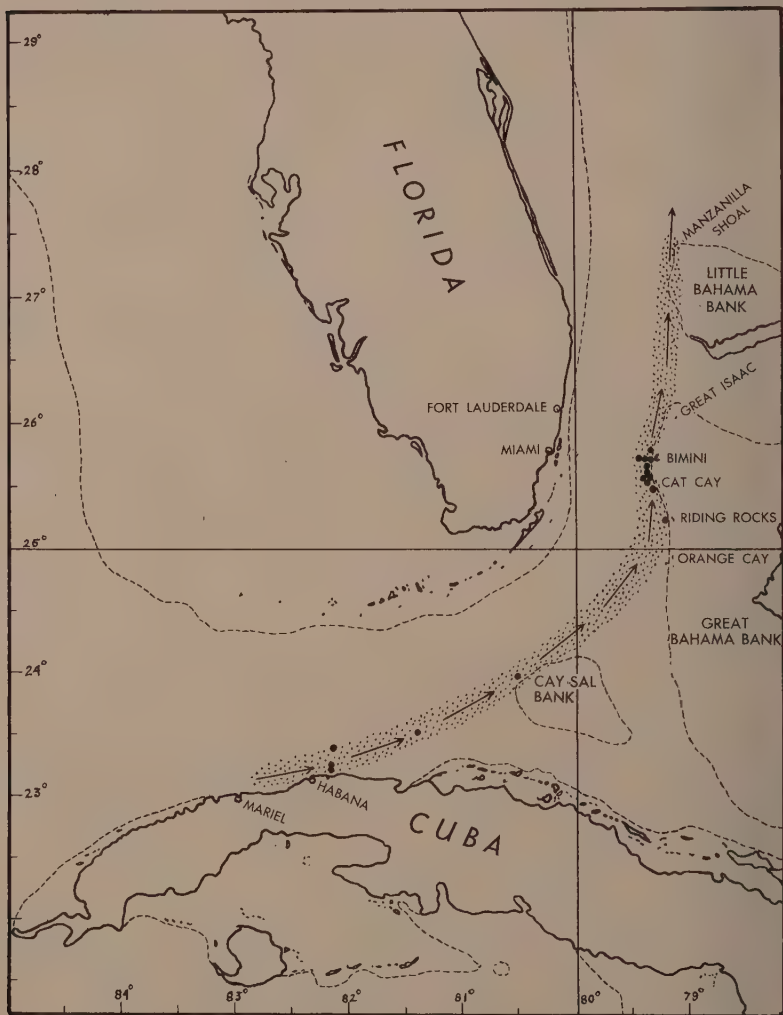


FIGURE 1. Chart of the Straits of Florida (modified after U.S. Navy Hydrographic Office No. 1411) showing presumed migratory route (arrows) and spawning area (stippled) of western north Atlantic bluefin tuna (*Thunnus thynnus*). Black dots indicate egg and larval fish collecting stations. (Table 3).

bluefin tuna weighing as little as 50 pounds are taken in considerable numbers. In addition, intensive air spotting conducted by private planes and by the writer through the cooperation of the United States Coast Guard, has failed to reveal the presence of smaller individuals. Aerial observations were conducted from an altitude of about 300 to 500 feet and the tuna were easily seen in the clear, shallow water against the sandy bottom, and objects as small as flying fish were easily detected. The schools vary in size from a pair to groups of several hundred individuals (usually 5 to 100), as determined by aerial and surface observations (Figure 2).



FIGURE 2. Aerial view of school of bluefin tuna (*Thunnus thynnus*) in shallow water off Cat Cay, Bahamas. (Photograph courtesy of George A. Bass).

TABLE 1

Frequency distribution of size by weight in pounds (lengths not available) of 451 bluefin tuna landed by anglers at Cat Cay, Bahamas during the period comprising May and June of the years 1941, 1947-1949 and 1951-1953. Weights in group intervals of 50 pounds. The smallest fish weighed 292 pounds, the largest 719. Data from records kept for Cat Key Club and kindly furnished by Mr. John Mahony.

	250-300	300-350	350-400	400-450	450-500	500-550	550-600	600-650	650-700	700-750
1941		4	20	32	17	4	2	3		
1947		2	5	15	15	8	4	3	1	
1948		2	9	20	19	13	10	6	1	1
1949	1		3	8	12	10	3	4		
1951		1	5	7	10	3	2	1		
1952	2	5	20	41	25	9	8	1		
1953		3	9	20	14	6		1		1
	—	—	—	—	—	—	—	—	—	—
Totals	3	17	71	143	112	53	29	19	2	2

CORRELATION OF GONAD CONDITION WITH TIME
AND PLACE OF OCCURRENCE

During the Bahama bluefin tuna season, in May, 1952, 1953, and 1954, the gonads of 95 individuals of both sexes ranging from 1997 to 2550 mm in length and 297 to 746 pounds in weight, were examined at Cat Cay. These fish were all captured by anglers in the waters adjacent to Cat Cay, from Riding Rocks to Bimini (Figure 1). In 1952, 35 individuals were dissected of which 10 (29%) were males, and 25 (71%) females. In 1953, of 31 individuals dissected, 8 (26%) were males, and 23 (74%) females. In 1954, of 29 individuals dissected, 11 (38%) were males, and 18 (62%) were females.

No milt was observed to issue from the genital opening of the males even upon application of considerable external pressure to the abdominal area, nor when the testes were actually squeezed upon removal from the abdominal cavity. In certain gonads, very strong squeezing would produce a few drops of milt. Dissection revealed the presence of small amounts of milt in the central ducts. The testes were solid, tough, greatly enlarged and of a pinkish white color. They filled most of the abdominal cavity and were considerably larger than those of a number of males of the same size range examined at Wedgeport, Nova Scotia, in August, 1953. No trace of milt was found in the testes of bluefin tuna in Nova Scotia. (See also Crane, 1936: 210.) As already pointed out by Marr (1948) it is difficult to distinguish between ripening and spent testes of tunas, but the conditions noted above are considered to be strongly indicative that the testes were recently spent rather than in a ripening condition. This view is further confirmed by the definitely ripe or spent condition of the females examined, as explained below.

The ovaries of all but one of the 25 females examined in 1952 were also recently spent. The ovaries of the single fish considered as showing a partly spent condition still contained a number of eggs in the follicles and lumina visible to the naked eye. In 1953, the ovaries of 3 females were found to be in a ripe condition and those of the other 20 were recently spent. In 1954, one female was found to be ripe and the other 17 recently spent.

The ovaries considered to be ripe were turgid, rounded in cross section greatly enlarged and filled most of the abdominal cavity extending to more than two thirds its length. The coloration was light yellow and the superficial blood vessels were enlarged and conspicuous. Ova in various stages of development suggesting fractional

spawning, filled the ovaries, and were preserved in formalin after being kept in sea water for some time. The smaller eggs were non-spherical, opaque and measured 0.4 to 0.7 mm in diameter with a mode of about 0.6 mm. The larger eggs were spherical, translucent, yolk-filled, and measured 0.7 to 1.1 in diameter with a mode of about 0.9 mm (Table 2). External pressure on the abdomen prior to dissection, produced extrusion of eggs as well as squeezing of the ovary upon removal from the abdominal cavity. The ova obtained in this manner were of the larger size just described, and apparently ready to be immediately spawned.

TABLE 2

Frequency distribution of size (diameter in mm) of ripe eggs from ovary of bluefin tuna (*Thunnus thynnus*) 2229 mm in fork length and 434 pounds in weight, captured in the vicinity of Cat Cay, Bahamas, on May 23, 1953.

0.7	0.8	0.9	1.0	1.1
16	86	105	55	4

The spent ovaries were somewhat less large, still distended, hollow, flaccid and their superficial blood vessels were still enlarged and conspicuous indicating very recent spawning.

The small number of ripe (males: 0%; females 6%) in relation to the large number of spent gonads (males: 100%; females: 94%) occurring in the individuals examined in the Bahamas, indicates that spawning is nearly terminated when the fish arrive in the Riding Rocks-Cat Cay-Bimini area or that the method of capture (rod and reel; see Farrington, 1949a, 1949b), is selective for spent individuals. As already suggested by Schaefer and Marr (1948), and June (1953) for the Pacific yellowfin tuna ("*Neothunnus macropterus*"), it may well be that the western Atlantic bluefin tuna also cease or decrease feeding during spawning, and that the taking of bait is not resumed until the individuals are spawned out. This view is supported by the bait-taking behavior, and the small size of the stomach and nature of its contents.

During the Bahama seasons of 1952 and 1953, the writer observed the behavior of the tuna as the schools were baited by the anglers. It was noted that certain schools produced negative results, in spite of repeated passing of the trolled bait in front of most of the individuals composing the school. All of the captured individuals came from schools in which the fish took the bait readily and often several individuals would strike simultaneously and eagerly at the same bait.

According to George A. Bass (personal communication), who has fished Bahama waters for several years, the "striking rate" of bluefin tuna increases towards the latter part of the season (late May, early June). His records show that during the early part of May, 1952, no strikes were obtained from the first 35 consecutive schools baited during a period of about a week. On the other hand, strikes were obtained out of practically every school baited during early June of the same season. In regard to the Australian southern bluefin tuna ("*Thunnus maccoyii*"), Serventy (1941: 32) states that "The large specimens occurring at Albany in the summer months . . . refuse to take the hook, but this is due to the fact that the fish are in a spawning condition, and similar behavior is known in like circumstances in the European tunny."

Compared with the stomachs of individuals examined at Wedgeport, Nova Scotia, during August, 1953, those of the fish examined at Cat Cay were mostly empty and considerably shrunk. This is indicated by the length of the stomach measured from its tip to the tip of the heart, expressed as the percentage of the length of the abdominal cavity measured from the tip of the heart to the anterior margin of the vent. In the Bahama fish, the length to tip of stomach was 31.1 to 52.5, whereas in the Wedgeport fish it was 52.2 to 67.5. The stomachs examined at Wedgeport were mostly full and distended. Of 34 stomachs examined by Crane (1936:211) at Portland, Maine, during the latter part of July, 1936, only 5 were empty. Gregory (*in* Serventy, 1941:31) reporting on the early summer occurrence of the Australian southern bluefin tuna in Albany harbor, states that "It seems to be definitely established that the tuna never feed in the harbour; their stomachs are invariably empty. Every tuna cut up by the fishermen had enlarged roes or milts."

It may be concluded from the foregoing, that the high percentage of recently spent individuals observed does not necessarily mean that spawning is nearly terminated when the fish arrive in the Riding Rocks-Cat Cay-Bimini area. If the method of capture is selective for spent individuals as discussed above, there may then be a higher percentage of ripe individuals actually occurring in the population. The occurrence of ripe as well as recently spent individuals indicates however, that spawning is actively taking place in that area although the spawning grounds may also extend farther to the north and south (Figure 1).

Since as already pointed out, the bulk of the migration does not arrive in the area until about the middle of May, and only a few

scattered individuals are seen towards late April, spawning in this area probably does not begin until early May. The almost sudden disappearance of the fish towards the middle of June and their reappearance in northern waters in late June and early July, would seem to indicate that the spawning season does not extend much beyond the middle of June, as also indicated by the rate of growth of the young. (See last section and Figure 3.)

The occurrence of only large individuals weighing not less than about 300 pounds (Table 1) in the Bahama spawning migration, does not necessarily mean that sexual maturity, in the western north Atlantic bluefin tuna, is restricted to that large size and that other spawning grounds may not exist elsewhere. In connection with the Mediterranean bluefin tuna, Heldt (1930: 45) refers to Sella as stating that the smaller individuals spawn later and that around Sicily the spawning season lasts through August for them. This does not agree with the findings of Westman and Neville (1942: 24) for the western north Atlantic bluefin tuna. According to these authors, bluefin tuna of both sexes from Long Island waters which are five years old and older, appear to be adult fish although the gonads gave no indications of the presence of eggs or sperm throughout the summer. As calculated from Westman and Gilbert (1941: 72, Figure 3) and Westman and Neville (1942: 20, Figure 10) a five year old bluefin tuna would weigh about 95 pounds and a Bahama 300 pound fish would be no less than about ten years old. It would seem therefore, that the age groups between five and ten years corresponding to a size range of about 95 to 300 pounds, spawn independently in areas and seasons as yet undetermined or else that they have not yet reached sexual maturity.

CORRELATION OF EGGS, LARVAE, AND JUVENILES WITH TIME AND PLACE OF OCCURRENCE

Once it was determined from the condition of the gonads that the fish were probably spawning in the Riding Rocks-Cat Cay-Bimini area, plankton tows were conducted in order to obtain eggs and larvae (Table 3 and Figure 1). Also, the stomach contents of various predatory fishes such as dolphin (*Coryphaena*) were examined whenever possible for the purpose of obtaining juveniles. Most of the tows were conducted along the path of the migrating tuna, from Riding Rocks to Bimini during May and June, 1952, 1953.

A few tows were also obtained southwestward to Havana, Cuba, along the outer edge of the Florida Current, during May, 1952 and

TABLE 3

Surface egg and larvel-fish tows conducted by the author (FR stations) along the outer edge of the Florida Current, from Havana, Cuba to Bimini, Bahamas, during May and June, 1952 and April to June, 1953. The geographical location of the stations is graphically indicated in Figure 1.

Station	Lat. N.	1952		Date	Temp. (C°)
		Long. W.			
FR-6	25° 14'	79° 12'		May 2	25.7°
FR-7	23° 58'	80° 29'		May 2	25.9°
FR-8	23° 30'	81° 23'		May 3	26.7°
FR-10	25° 14'	79° 12'		May 5	26.4°
FR-12	25° 33'	79° 19'		May 20	26.9°
FR-13	25° 33'	79° 19'		May 22	27.3°
FR-14	25° 43'	79° 20'		June 5	27.2°
FR-15	25° 36'	79° 20'		June 6	28.0°
FR-16	25° 43'	79° 22'		June 9	27.8°
FR-17	25° 43'	79° 20'		June 10	
FR-18	25° 43'	79° 20'		June 12	29.5°
FR-19	25° 42'	79° 21'		June 15	28.6°
1953					
FR-29	23° 15'	82° 8'		April 17	25.8°
FR-31	23° 14'	82° 8'		April 18	26.2°
FR-32	23° 15'	82° 8'		May 1	26.6°
FR-33	23° 23'	82° 10'		May 2	27.0°
FR-34	25° 43'	79° 18'		May 8	24.9°
FR-35	25° 34'	79° 23'		May 9	25.4°
FR-36	25° 30'	79° 19'		May 9	25.3°
FR-37	25° 48'	79° 20'		May 10	26.0°
FR-38	25° 43'	79° 25'		May 10	28.0°
FR-39	25° 36'	79° 20'		May 27	26.2°
FR-40	25° 34'	79° 20'		May 29	26.1°

April and May, 1953, since it appeared possible that the fish might travel along this path and might be already spawning before arriving in the Riding Rocks area (Figure 1). As already indicated no bluefin tuna are ever seen along the edge of the Bahama Bank south of Orange Cay, but schools are occasionally seen in May from low flying scouting planes along the northwestern edge of Cay Sal Bank (Messrs. Julio and Thorvald Sanchez, personal communication). In addition, a few individuals are taken every year during May and June by commercial fishermen in the vicinity of Havana, Cuba. Photographs of two large bluefin tuna taken by commercial fishermen off Mariel (25 miles west of Havana) in May, 1949, were recently presented to the author by Mr. Ernest Hemingway.

All the fish eggs and scombrid larvae were segregated from the

plankton samples and a further segregation of tentatively identified *Thunnus* eggs and larvae was conducted later. The egg samples from station 39 were accidentally lost before study and samples from stations 6, 7, 8, 10, 12, 34, and 38 contained no tuna eggs. Usually tuna eggs occurred in greater numbers than any others in the plankton samples. Tentatively identified tuna larvae were obtained in stations 16, 17, 18, 32, 33, 38 and 40. A juvenile bluefin tuna in good condition, measuring 45 mm in fork length was obtained from the stomach of a dolphin (*Coryphaena hippurus*) captured off Miami, Florida, on June 9, 1953. This specimen was easily identified by the number of dorsal spines, rays and finlets ($14+14+8 = 36$), the number of anal rays and finlets ($13+8 = 21$) and the gill raker count (25 on lower limb of first arch) which is higher than in any other species of *Thunnus* (Rivas, 1951).

As already indicated in the preceding section, the ripe ovarian eggs of the Bahama bluefin tuna are spherical, possess a very thin, smooth membrane and measure 0.7 to 1.1 mm in diameter with a mode of 0.9 mm (Table 2). The fertilized egg of the Mediterranean bluefin tuna is also spherical, smooth, and measures 1.0 to 1.12 mm in diameter, with a single, rather large oil globule of about 0.27 mm, (Sanzo, 1932). In Sanzo's detailed illustrations, the fertilized egg is shown in various stages of development to near hatching. As the embryo develops, the oil globule appears surrounded by micromelanophores and keeps a position more or less equidistant from the head and tail of the embryo. In more advanced stages, from about 22 hours before hatching, the embryo is also covered with micromelanophores.

Comparison of the planktonic eggs obtained in the tows with the descriptions and figures of Sanzo, revealed numerous ova in various stages of development agreeing with those of the Mediterranean bluefin tuna and markedly distinct from all the others. Representative, random samples of these eggs from various stations were measured and found to agree in range and mode with the ripe ovarian eggs, as shown in Tables 2 and 4. The oil globule of these planktonic eggs measures 0.18 to 0.32 mm in diameter, with a mode of about 0.25 mm.

The slight discrepancy in size between the European bluefin tuna eggs (1.0 to 1.12) and those herein discussed (0.7 to 1.1, mode 0.9 mm) indicates that the latter are somewhat smaller. This, rather than introducing a disturbing factor in identification, is to be expected, and may be explained on the basis of the water temperatures at which the eggs are matured and spawned on each side of the Atlantic. The sur-

TABLE 4

Frequency distribution of size (diameter in mm) of planktonic eggs tentatively identified as bluefin tuna (*Thunnus thynnus*) from tows conducted along the outer edge of the Florida Current. See Table 3 for data on stations.

Station	0.7	0.8	0.9	1.0	1.1
FR-13			1		
FR-14			2	1	
FR-15	9	5	35	10	
FR-16		14	37	11	3
FR-17	3	7	13	4	1
FR-18	8	11	27	7	3
FR-19	1	2	6	6	3
FR-29			2	1	1
FR-31			2	8	1
FR-33			8	9	1
FR-35	2	9	25	14	4
FR-36			1	4	1
FR-37		2	3	3	1
FR-40		3	7	4	2
Total	23	53	168	82	21

face temperatures of the spawning grounds during the spawning season in the central Mediterranean (Roule, 1924), range from 19° to 21.6° centigrade (average about 20°). The surface temperatures of the spawning grounds in the Straits of Florida, from Havana to Bimini, range from 24.9° to 29.5° (average 26.7°) during the period from April 18 to June 15 (Table 3). Spawning takes place therefore at much higher temperatures in the western Atlantic and according to the evidence available, this would cause the eggs to be smaller (Ehrenbaum, 1921: 4; Fish, 1928: 291-292; Sette, 1943: 166).

Several of the fertilized eggs tentatively identified as those of tuna were collected close to shore off Bimini and hatched in finger-bowls at the Lerner Marine Laboratory, in early June, 1952. The resulting larvae agreed with Sanzo's descriptions and figures (1932) for the Mediterranean bluefin tuna.

The 96 larvae herein tentatively identified as *Thunnus* measure 3.5 to 8 mm in length, and are similar to those described as *Orcynus* (= *Thunnus*) *germo* and *thynnus* by Ehrenbaum (1924: 20-28), and *Neothunnus* (= *Thunnus*) *macropterus* by Wade (1950: 395-399; 1951: 458-465) and Mead (1951: 123, 124). The larva of *Thunnus* is well characterized by a combination of characters involving mainly the preopercular spinescence, the dense, black pigmentation of the high, anterior dorsal fin and the number of vertebrae (39). The only

other genera of scombrids possessing 39 vertebrae and occurring in the Straits of Florida are *Auxis* and *Euthynnus* (Rivas, 1951). The larvae of these genera can be readily distinguished, however, from those of *Thunnus*, by the much lower and much less heavily pigmented anterior dorsal fin. In addition, the anterior and posterior dorsal fins are widely separated in *Auxis* and *Euthynnus* but continuous in *Thunnus* at comparable lengths (Ehrenbaum, 1924; Wade, 1951).

A study of the literature (Ehrenbaum, 1924; Schaefer and Marr, 1948; Wade, 1950, 1951; Mead, 1951) shows that although the larval stages of *Thunnus* (*sensu lato*) can be distinguished from those of other genera of scombrids, the various species within the genus are very difficult to separate. It would seem therefore, that the eggs and larvae of any given species of *Thunnus* from any given geographical region could be more definitely identified only by correlating the time and place of occurrence of the eggs and larvae with the time and place of spawning activity of the adult as indicated by gonad condition.

In addition to *Thunnus thynnus*, the only other species of the genus occurring in the Straits of Florida (Rivas, 1951) are *T. atlanticus* (blackfin tuna), and *T. albacares* (Allison tuna)². The latter is rarely taken in the Straits of Florida and during the time of spawning activity of the bluefin tuna, none were taken in 1953 and only one was captured on June 3, 1952, off Bimini, by W. W. Fisher of Ferndale, Michigan. This specimen weighed 165 pounds and measured 1531 mm in fork length. Despite the relatively large size attained by this species and its schooling habits similar to those of the bluefin tuna, no schools or single individuals were seen from the air in the area occupied at the time by the bluefin tuna. The blackfin tuna, a much smaller species rarely weighing more than about 20 pounds, occurs in the Straits of Florida throughout the year. The spawning grounds, spawning season, eggs, larvae and juveniles of the blackfin and Allison tunas are still unknown.

It would seem therefore, that the eggs and larvae herein discussed, could be those of either *Thunnus thynnus*, *T. atlanticus* or *T. albacares*. However, in the light of the above discussions the probability seems to be in favor of *T. thynnus*. Until more accurate methods of identification are worked out, the identity of these eggs and larvae must remain tentative.

²Ginsburg (1953: 3-6) has shown that *albacares* rather than *argentinatus* is a correct name for Atlantic yellowfin (Allison) tuna. The present writer does not agree with Ginsburg however, in that the western (*subulatus*) and eastern (*albacares*) Atlantic populations represent separate species.

The occurrence of juveniles off southeastern Florida indicates the existence of spawning grounds not far away, and the recently spent condition of the fish captured in the Bimini-Riding Rocks area indicates that spawning occurs to the south or even in the immediate vicinity. The probability of selective capture further indicates that spawning may extend a certain distance north of the area. The evidence based upon planktonic eggs and larvae although admittedly tentative, is nevertheless completely in line with this conclusion. (Figure 1).

CORRELATION OF RATE OF GROWTH OF YOUNG, WITH TIME AND PLACE OF OCCURRENCE

According to data available on the young of the European bluefin tuna, it was assumed that those of the American fish should be obtainable in the vicinity of the spawning grounds, and that their rate of growth would give confirmative information as to the spawning season. Heldt (1930: 45,46) on the basis of data supplied by Sella and Duc d'Ossada, had shown that the young of the Mediterranean bluefin tuna attain a weight of about 300 grams in two to three months. Individ-

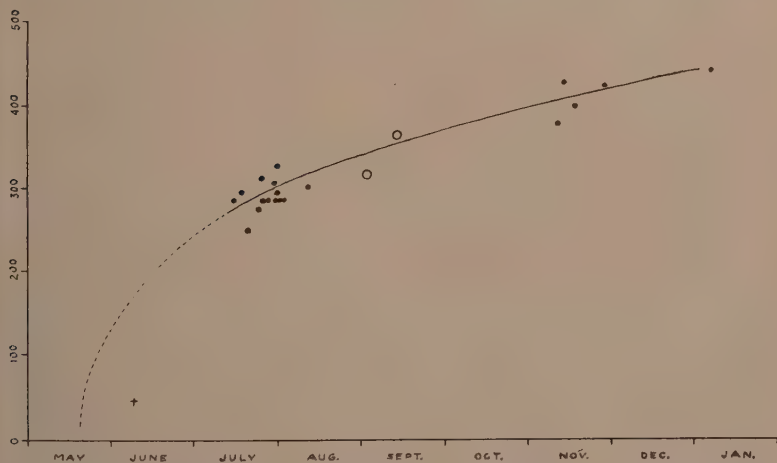


FIGURE 3. Rate of growth of young bluefin tuna (*Thunnus thynnus*) from the Straits of Florida, in terms of length (mm) and date of capture relationship. Based on data from Table 5. Cross represents 45 mm juvenile from off Miami (June 9), and open circles represent specimens from Brielle, New Jersey (September 2), and Montauk, Long Island (September 12).

uals of this size measure about 250 mm in fork length and can be taken by means of the smaller surface trolled feathers used by anglers operating from the various fishing centers located along the south-east coast of Florida.

In the warmer waters of the Florida Current, it was expected that the young would grow faster, and according to the assumed peak of the spawning season (second half of May) individuals could be captured as early as mid-July. Through the kind cooperation of Al Pflueger and Captain Oskar Schubert of Miami, and Joseph T. Reese of Fort Lauderdale, 19 specimens 250 to 446 mm in fork length (297 to 1699 grams) were obtained from the area comprised between Fort Lauderdale and Miami, in July, August, November and January (Table 5). This material has enabled the construction of a rate of growth curve (Figure 3) drawn to fit the position of the specimens, and continued as a normal growth curve. The results are in accordance with the position of the 45 mm juvenile and the assumed peak of the spawning season as suggested by the duration of the peak of the spawning migration (middle of May to early June).

TABLE 5

Fork lengths (mm) and dates of capture of young bluefin tuna (*Thunnus thynnus*) from the Straits of Florida (Miami to Fort Lauderdale). All specimens collected in 1953 except the November 12 (1952) and January 5 (1951) records.

<i>Length</i>	<i>Date</i>	<i>Length</i>	<i>Date</i>
285	July 14	329	July 29
298	July 17	286	July 30
250	July 19	286	July 31
278	July 23	301	August 10
313	July 24	380	November 10
287	July 24	431	November 12
289	July 26	404	November 16
287	July 29	428	November 27
303	July 29	446	January 5
298	July 29		

The presence of young bluefin tuna in the Straits of Florida until early August, their apparent absence during the rest of the summer and their reappearance in November, suggests that these young fish may migrate to northern waters and return in the fall. Westman and Neville (1942:24) report the occasional capture of very small fish in northern waters (Long Island) during the summer, and Westman and Gilbert (1941:71) have recorded a young bluefin 12.5 inches

(317 mm) in fork length, taken off Brielle, New Jersey, on September 2, 1939. A specimen 366 mm long was taken 30 miles south of Montauk Point, Long Island, by B. Arata, on September 12, 1952. These two specimens were included in Figure 3 after the curve was constructed on the basis of Florida Strait specimens, and appear to be the result of May-June spawning in the latter area.

The occurrence of young bluefin tuna about 2 months old in the Straits of Florida does not necessarily mean that these fish are the result of spawning which has taken place in areas much farther to the south in the Caribbean. The growth curve (Figure 3) indicates that these fish are the result of spawning during May but during that time the greatest known concentration of adult, spawning fish is located in the Straits of Florida as already discussed. In addition, young bluefin tuna, according to the information available on the European fish, remain in the vicinity of the spawning grounds at least for two months (Heldt, 1930:45,46).

It would seem therefore, that in the Straits of Florida, the spawning grounds of the bluefin tuna do not extend much farther west than northwestern Cuba. Further investigations are needed before a more accurate delimitation of these spawning grounds is established.

CONCLUSIONS

The evidence presented in this study indicates that the western north Atlantic bluefin tuna spawns in the Straits of Florida along the outer margin of the Florida Current during May through the middle of June. The most active spawning appears to take place during May in the area comprised from Riding Rocks to Bimini, along the western edge of the Great Bahama Bank. Possibility of the existence of other spawning areas elsewhere is not excluded.

The northward direction of the spawning migration, the time of occurrence of the fish in Bahama waters (May through mid-June) and the time of their appearance in northern waters (from late June on), correlated with a corresponding sequence of gonad condition and feeding habit, seem to indicate that all these fish probably belong to the same population. This assumption refers only to the larger fish of about 300 pounds or more, since, as previously discussed, the smaller adults of about 95 to 300 pounds are not involved in the Bahama spawning migration and their whereabouts are unknown except during summer and early fall. Their spawning grounds and season are also unknown. Further confirmation of migration and popula-

tion identity is dependent, of course, on accurate biometric data, tagging and other information. This is now in process of investigation.

The spawning seasons of the European and American Atlantic bluefin tuna are now known to overlap in time and their respective spawning grounds are located about 4000 miles apart. It is therefore assumed, pending confirmation from biometric and distributional studies, that the eastern and western north Atlantic bluefin tuna represent separate, independent units.

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INORGANIC PHOSPHATE MEASUREMENT IN SEA WATER¹

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ABSTRACT

A colorimetric inorganic phosphorus technique heretofore employed with tissue fluids has been adapted for use in sea water. The reagent, containing sulfuric acid, ammonium molybdate, and ascorbic acid, is sensitive to concentrations as low as 0.016 $\mu\text{g-at P/L}$, and standard curves have been constructed to cover the following ranges: 0.016 - 2.26 $\mu\text{g-at P/L}$, using 100 ml samples, and 2.26 - 32.2 $\mu\text{g-at P/L}$ using 10 ml samples.

Freshly prepared ascorbic acid reagent was found to be chemically viable for at least 12 hours. Upon the addition of the proper amount of reagent to an unknown or standard sample, maximum time of color development was found to be between 8 and 12 hours. This color intensity persisted for at least 95 hours. Best results were obtained at room temperature, and all measurements were made in a Beckman Quartz Spectrophotometer, Model DU at wavelength 820 $m\mu$ using either 10 cm or 1 cm cuvettes.

INTRODUCTION

Studies on biological productivity in the oceans necessarily include inorganic analyses of the sea water medium. Among the elements of particular interest, phosphorus has received considerable attention not only because of its importance in both plant and animal nutrition, but also by reason of the difficulties involved in its quantitative estimation.

Colorimetric methods of phosphate measurement were developed early (Pouget and Chouchak, 1909, 1911, and Matthews, 1916-1918). Standard procedures in use today are based on the later studies of Denigès (1921) and Atkins (1923). Briefly, these utilize the principle of measurable blue color formation (625 $m\mu$) by phosphomolybdate in the presence of stannous chloride. Difficulties are still experienced by workers using this technique since the blue color loses intensity after relatively short periods; the sensitivity is not sufficient for accurate measurement of the small amounts of phosphate found in some ocean waters; and considerable positive error results when arsenic is present in the test sample.

Of the many methods for estimation of phosphate in tissue fluids and tissue extracts, that of Fiske and Subbarow (1925) has gained wide acceptance. The reduction of acidified phosphomolybdate is

¹Contribution No. 133 from the Marine Laboratory, University of Miami.

accomplished here by aminonaphtholsulfonic acid, and the resulting blue color (820 m μ) is both sensitive to micro-quantities of phosphorus and quite stable for long periods (at least 24 hours). Griswold, Humoller, and McIntyre (1951) improved the sensitivity of the colorimetric technique and concentrated the inorganic phosphorus by first precipitating it as magnesium ammonium phosphate. Lowry, Roberts, Leiner, Wu, and Farr (1954) found that the substitution of 1% ascorbic acid for the aminonaphtholsulfonic acid of the Fiske-Subbarow reagent resulted in the formation of a highly colored reduction product capable of measuring 3 millimicrograms of inorganic phosphorus in a final volume of 45 microliters.

The latter method on a larger scale, was finally adapted for sea water phosphate determinations but not before considerable time had been spent in the exploration of other techniques. Biological productivity studies are currently in progress in the Gulf Stream where phosphate concentrations are sometimes lower than 0.1 $\mu\text{g-at L}$, consequently the problem lay in the detection of small amounts of phosphate in large volumes of water. At the outset, all attempts to solve the problem were based on the assumption that existing methods of analysis could be used if the "apparent" phosphate content could be raised; i.e., the volume of solution decreased. To accomplish this, phosphate ion was removed from the original sample by means of ion exchange, adsorption on glass particles, and precipitation from liter aliquots as magnesium ammonium phosphate. For the re-solution of the removed fraction, small volumes of solvent were used. Unfortunately considerable manipulation was required for each procedure, and the results were too inconsistent to warrant further consideration.

Analyses of sea water phosphate samples without concentrating volumes were then tried using an ascorbic acid reagent based on that employed by Lowry *et al*. The success of these experiments prompted further investigation into the technique which was subsequently adopted for routine analyses.

The authors wish to acknowledge the assistance of the Rockefeller Foundation whose financial grant made possible the completion of this project.

MATERIALS AND METHODS

As stated previously, the ascorbic acid reagent requires the substitution of 1% ascorbic acid for the Fiske-Subbarow amine. Although the technique as set down by Lowry *et al* is sensitive to micro-quantities of inorganic phosphorous, the volume of test sample which they

employed (5 μL) was much too small to be considered for sea water analyses. The aliquots used for the latter (100 ml) represented a 4000-fold increase in the volume of solution to be tested, however the final concentration of reagents was kept constant. Because of the necessary change in technique, the smallest amounts of phosphate detected by Lowry *et al* could not be determined, but concentrations as low as 0.016 $\mu\text{g-at P/L}$ were observable with adequate precision. Using 100 ml samples, the range of method was from 0.016 $\mu\text{g-at P/L}$ to 2.26 $\mu\text{g-at P/L}$. For higher concentrations, 10 ml aliquots were used, and the range was extended from 2.26 $\mu\text{g-at P/L}$ to 32.2 $\mu\text{g-at P/L}$.

In addition to the advantage of high sensitivity possessed by the reagent, it is noteworthy that silicate does not interfere with it, and arsenate present in the solution on an equimolar basis gives only 1/5 the color of phosphate.

Reagent.

To each 100 ml of unknown or standard solution was added the following reagent mixed in the order shown:

10 ml solution containing 134 meq H_2SO_4 (ACS)

10 ml solution containing 0.335 gm ammonium molybdate tetrahydrate $(\text{NH}_4)_6\text{Mo}_7\text{O}_{24} \cdot 4\text{H}_2\text{O}$ (AR)

5.3 ml distilled water

10 ml solution containing 1.34 gm ascorbic acid (USP)

Total volume of reagent = 35.3 ml

To each 10 ml of unknown, 3.53 ml of the reagent was added.

For best results the reagent was made up fresh but was found to be stable within a few hours after mixing especially if it was kept cool. When used for tests in the field or at sea, the first three ingredients of the reagent were mixed in the laboratory and kept in a glass-stoppered reagent bottle. The required amount of ascorbic acid was weighed out and the dry powder kept in vials sealed with Parafilm and kept in the dark. When reagent was needed, the ascorbic acid powder was transferred to a graduated cylinder and diluted to 10 ml. This was then added to 25.3 ml of the previously prepared acid molybdate and the resulting mixture transferred to 100 ml of the solution to be tested. For 10 ml test samples, 1/10 the amount of the above reagent is used.

Diluting Medium for Standards.

In making up standard and reagent blank solutions, the most desirable medium is sea water devoid of phosphate. It was found

that sea water from the surface of the Gulf Stream was very low in phosphate content. Samples were collected in five gallon carboys, and after an aging period of several days the existing phosphate appeared to be taken completely out of solution; i.e., the water showed all evidence of being phosphate-free. It is worthy of mention that in the course of productivity studies at the laboratory, sea water was obtained by pumping samples from various depths and centrifuging them in a Sharples Super-Centrifuge to remove particulate matter. Consequently, the samples thus obtained were assumed to contain only dissolved phosphorus.

At the inception of this study, reagent blanks consisted of the phosphate-free Gulf Stream water to which reagent had been added. Since it might be considered desirable to obtain sea water blanks from other areas in question, some thought was given to the treatment of such waters in order to remove phosphate from them by processes other than aging.

Having previously noted that raising the pH of sea water with sodium hydroxide caused precipitation of some of its salts, it was thought that such a precipitate would include any phosphate present in the sea water as an insoluble phosphate, adsorbed phosphate, or both. A 100 ml sample of Gulf Stream sea water taken well below the surface and known to contain phosphate was treated with 1 meq NaOH (0.1 ml of 10N solution) and mixed well to disperse the precipitate. The clear supernatant obtained after centrifugation was then acidified with the addition of 2 meq H_2SO_4 (0.2 ml of 10N solution) and tested for phosphate. Control tests were run on untreated samples, distilled water, and aged sea water containing no phosphate.

Both dilution media and unknown sea water samples to be analyzed were made approximately 0.1 N with sulfuric acid before the addition of reagent since, as Lowry *et al* have stated in the original method, the final sulfuric acid concentration should be close to 1 N in order to obtain optimal color development in test solutions and minimum color in blanks (hence the addition of excess sulfuric acid to the base treated blanks).

Standard Solutions.

Working standards consisted of various dilutions of weighed dried KH_2PO_4 (CP). In making up primary standards, the dilution medium was kept 0.1 N with sulfuric acid. The range of standards was as shown in Table 1.

TABLE 1

$\mu\text{g P}/100 \text{ ml standard}$	$= \mu\text{g P}/\text{L}$	$= \mu\text{g-at P}/\text{L}$
0.05	0.5	0.016
to		
7.0	70.0	2.32
$\mu\text{g P}/10 \text{ ml standard}$		
0.7	70.0	2.32
to		
10.0	1000.0	32.3

Method.

Standard and unknown solutions were collected in either 125 ml erlenmeyer flasks or 8 oz polyethylene bottles. The latter were found to be more satisfactory for shipboard use. In either case, no difficulties were experienced from the leaching or dissolution of material from the walls of the containers providing they had been previously cleaned with chromic acid and rinsed with distilled water.

Unknowns were collected at sea by rinsing a graduate several times with the water to be tested, transferring an aliquot to the appropriate container, and adding 5 drops of concentrated sulfuric acid. When 10 ml samples were used, they were placed in 15 ml test tubes and $\frac{1}{2}$ drop of the acid added.

To each 100 ml or 10 ml of standard or unknown solution was added respectively 35.3 or 3.53 ml of the freshly prepared reagent. The container was immediately capped with Parafilm and the contents mixed. In all cases, color development was allowed to take place in the dark or in subdued light to obviate any possibility of light-oxidation of the ascorbic acid. After allowing the mixture to stand at room temperature for a minimum of 8-12 hours, the unknown or standard solutions were read against the reagent blank in a Beckman Quartz Spectrophotometer, Model DU at 820 $m\mu$ using 10 cm cuvettes.

Total Phosphorus.

Three standards containing respectively 0.00968, 0.035, and 0.0549 $\mu\text{g-at P}/100 \text{ ml}$ of Gulf Stream sea water were made up as before. A Gulf Stream sea water blank was included. The samples were digested as for total phosphorus using the method of Hansen and Robinson (1952). Upon completion of this treatment, the dry ashed samples were dissolved in distilled water and their volumes made up to 100 ml. Ascorbic acid reagent (25.3 ml) was then added to each sample and colorimetric measurement was made as before.

Effects of Temperature on the ascorbic acid reagent.

In addition to testing the ascorbic acid reagent at room temperature, samples were run in a 38°C water bath for two hours. This experiment was based on the standard method used by Lowry *et al* who employed this temperature for the color development in all their phosphate samples.

The reaction of the reagent was also observed under conditions of high temperature for short periods. This was accomplished by immersing phosphate samples containing reagent in a boiling water bath for 10 minutes. The samples were then cooled and read in the spectrophotometer.

Time of maximum color development and stability of the final color.

Subsequent to the addition of ascorbic acid reagent to room temperature samples, periodic measurements of color intensity were made in order to determine when the maximum color was attained. Such tests were continued beyond this point to ascertain the stability of the final color.

As noted previously, ascorbic acid reagent was always used shortly after being freshly mixed. This was based on the procedure of Lowry *et al*. In order to determine when the reagent lost its reactivity, samples of Gulf Stream sea water with a known phosphate content and to which reagent had been added, were analyzed at various intervals. After each analysis, a known amount of phosphate was again added and the increment in color intensity noted at the next interval.

Reaction of ascorbic acid reagent with organic phosphates.

Since inorganic phosphate analyses at room temperature require that the reagent-unknown mixture stand for considerable time, the possibility existed that any dissolved organic phosphate present might decompose in the acidified solution releasing more inorganic phosphorus which could then react with the reagent and thus cause a positive error. Studies involving unstable organic phosphates were not considered since their presence in sea water would result in rapid, if not immediate, decomposition—which could not be prevented in any case. Consequently a rather stable substance, muscle adenylic acid, was arbitrarily chosen to test the reagent. Samples containing known amounts of adenylic acid phosphorus were subjected to the inorganic phosphate test while duplicate samples were digested for total phosphorus determination.

RESULTS AND DISCUSSIONS

Optical Characteristics.

The ascorbic acid reagent as prepared for sea water analyses is straw-colored when fresh. On standing, it darkens somewhat to a golden hue which persists for several days. At no time, however, is the blue phosphomolybdate color visible to the naked eye in standards containing less than $3.23 \mu\text{g-at P/L}$. The sensitivity of the reagent becomes apparent on examination of the spectral profile curve as shown in Figure 1. Here two Gulf Stream sea water samples, one containing $1 \mu\text{g P/100 ml}$ ($0.32 \mu\text{g-at P/L}$) and the other containing no phosphate are compared using distilled water with reagent as a blank. In the curve of the sample containing phosphate, a sharp peak is observed at $820 \text{ m}\mu$.

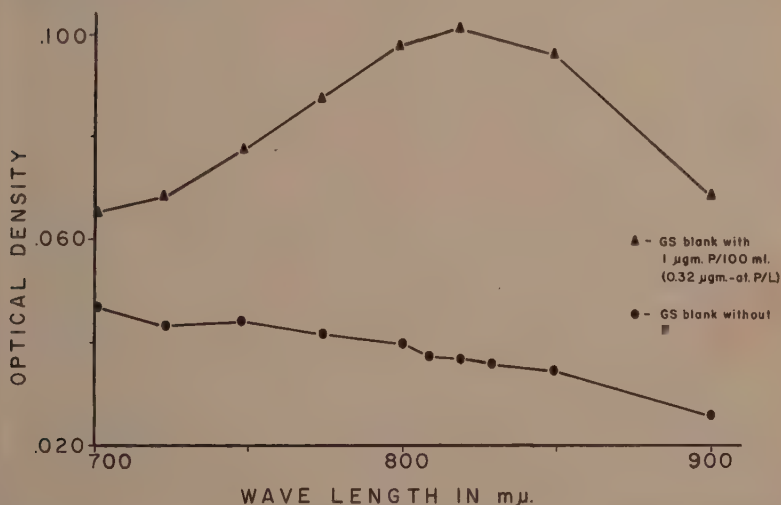


FIGURE 1. Spectral profile curve of Gulf Stream seawater—phosphate with ascorbic acid reagent added.

The general darkening of the reagent on standing (this becomes noticeable sometime after 12 hours) has no effect on the measurement of the existing blue phosphate color, at least for several days. It is not known whether the final breakdown of color intensity is due to the reagent or decomposition of the phosphomolybdate complex. In one instance erratic results were obtained on using a sample of ascorbic acid whose container had been exposed for considerable time to the

atmosphere, and which had been kept at room temperature. The powder (originally USP grade) appeared to be somewhat oxidized and gave a distinct dark yellow color to the reagent. Subsequent to this experiment, all samples of ascorbic acid powder (USP) were tightly sealed when not in use and kept in the refrigerator. While this procedure was essential to prevent decomposition of the substance over long periods, the weighed dry samples taken for shipboard use showed no evidence of deterioration at least for the duration of the cruises, which averaged two days.

It is noteworthy that ascorbic acid solutions kept at a pH below 4 slowly oxidize to form dehydroascorbic acid—a process which may be reversible in this acid range. Above this pH, however, dehydroascorbic acid is converted irreversibly to another reducing substance, which in turn gives rise to oxalic and threonic acids (Morton, 1942). Lowry *et al* have stated that in the pH range 0.6-3.0 an additional danger exists whereby ascorbic acid will reduce molybdic acid in the absence of phosphate. Consequently, the addition of the proper amount of sulfuric acid to both reagent and unknown may be regarded as critical.

Standard Curves.

The standard curve of phosphate samples incubated at room temperature is shown in Figure 2. As may be seen in 2a, the sensitivity of the method persists in samples containing as little as $0.05 \mu\text{g P}/100 \text{ ml}$ ($0.016 \mu\text{g-at P/L}$). The fact that the standard line does not pass through the origin in 2a and 2b is due to the difference in wall thickness between the two 10 cm cuvettes used for colorimetric measurement. This was not the case in 2c where 1 cm cells were used.

On 2b appear the readings obtained from the three samples used in the total phosphorus analysis. There is no apparent interference with the ascorbic acid reagent by the reagents used in the digestion. Furthermore, the digested sample is sufficiently acid to forego the further addition of sulfuric acid on diluting the material to volume before the addition of the color reagent.

Standard Blanks.

Figure 3 shows the results obtained from the base-treated sea water previously described (100 ml aliquots). Note that the curve of this sample is quite similar to that obtained with aged sea water while the control, consisting of the same Gulf Stream (GS) sea water sample which had received no base treatment, exhibits quite a large magnitude

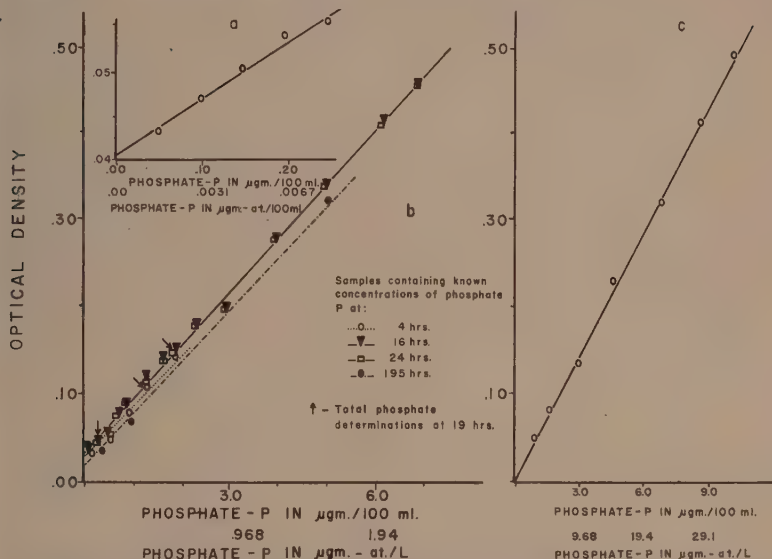


FIGURE 2. Standard concentration curves read at 820 mμ. Curves a and b are read in 10-centimeter cuvettes; curve c is read in 1.0-centimeter cuvette.

of phosphate with a distinct peak at 820 mμ. It would appear that the use of base to remove phosphate from sea water is effective without markedly changing the spectral characteristics of the resultant blank.

All the samples were read against distilled water containing reagent. The bottom curve is actually the same distilled water aliquot read against itself. The fact that the readings were at all obtained in this case further emphasizes the difference in optical characteristics between the two 10 cm cuvettes.

Time and temperature effects on the reagent.

The time required for maximum color development in room temperature standards is shown in Figure 2b. At 4 hours after the addition of reagent, maximum color intensity was attained in samples ranging up to 1.5 μg P/100 ml (0.5 μg-at P/L). Between 4 and 16 hours full development was observed for the complete set of standards. (Although not shown on this graph, the point of maximum color development was established on another sample as being between 8 and 12 hours.) No change in color intensity was observed at 24 hours. The stability of the reagent was extended when a series of unknowns

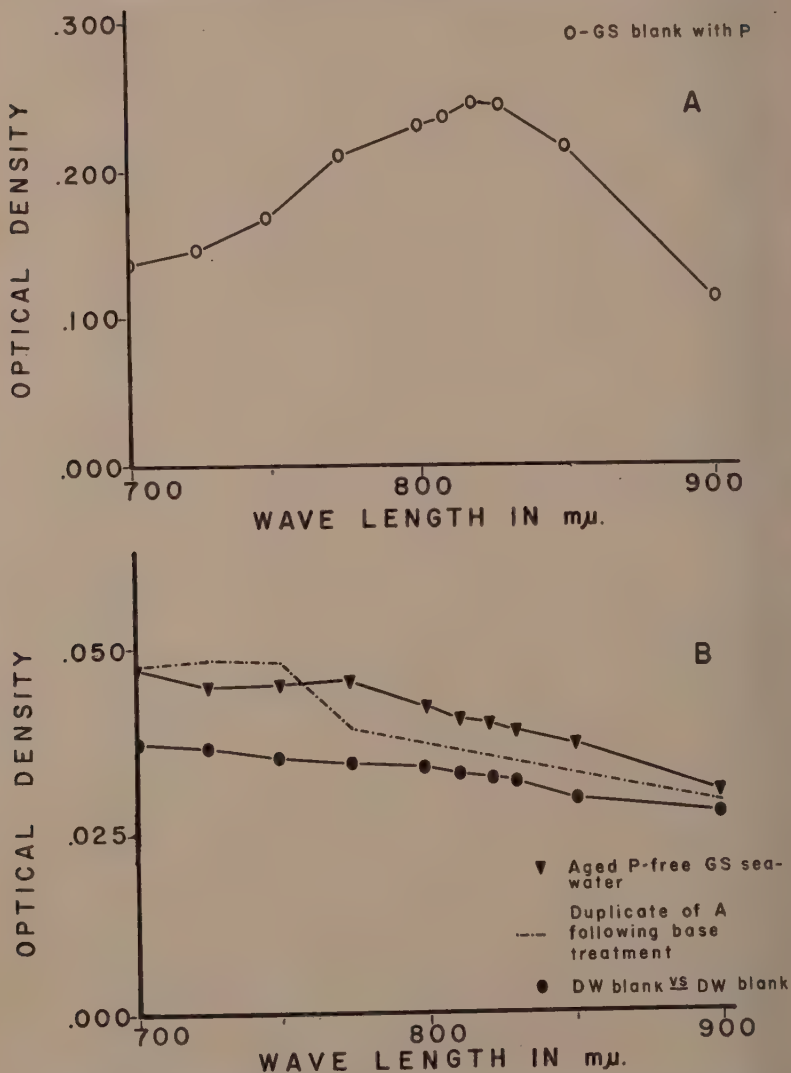


FIGURE 3. Spectral profile curve of three Gulf Stream seawater samples, and distilled water, used as reagent blanks.

obtained from the Gulf Stream were run at the above intervals and also at 36 to 93 hours with no change in the intensity noted after the maturity of the color. Figure 2 also shows the color intensity of the standards at 195 hours. Here the curve is observed to fall slightly off, the readings showing a drop of approximately 20%.

The results of the experiment designed to show the maximum period during which the ascorbic acid reagent is chemically viable are shown in Table 2.

TABLE 2

Total μg P in sample		Time of Reading	Optical density	
Sample 1	Sample 2		Sample 1	Sample 2
0.5	1.5	0		
"	"	4 hr.	.074	.132
(0.5 μg P added to both samples immediately after 4 hr. reading)				
1.0	2.0	8 hr.	.102	.164
(0.5 μg P added to both samples immediately after 8 hr. reading)				
1.5	2.5	19 hr.	.125	.186
(0.5 μg P added to both samples immediately after 19 hr. reading)				
2.0	3.0	24 hr.	.125	.185

From Table 2 it would appear that the reagent will no longer react with phosphate some time between 8 and 19 hours after it has been made up. Having established the fact that the time required for maximum color development for the range of standards used to be between 8 and 12 hours, the loss in reactivity may be fixed at a period somewhere between 12 and 19 hours after making up the reagent.

The samples incubated at 38°C for two hours did not show complete color development at the end of this period but required approximately the same time as the room temperature samples to show maximum intensity. The 38°C incubation period was used by Lowry *et al.*, but it is to be remembered that the volume of test solution employed in the latter case was only 45 μL (5 μL of sample plus 40 μL of reagent).

A standard curve based on the samples which had been maintained at 100°C for ten minutes was similar to that obtained from room temperature standards. After 24 hours, however, all readings showed an increase in optical density of .01. Upon repeating this experiment, it became apparent that a standard curve of boiled samples is reliable only if the latter are measured shortly after the completion of the boiling period.

Reaction of reagent with organic phosphate.

The two dilutions of adenylic acid used for this experiment contain-

ed 0.448 and 1.34 $\mu\text{g P}/100\text{ ml}$. Results of the test are shown in Table 3.

TABLE 3

$\mu\text{g organic P per sample}$	<i>Optical density of sample treated as for inorganic phosphate</i>	<i>Optical density of sample digested for total P before addition of reagent</i>
0.448	.039	.053
1.34	.038	.128

(Readings were made 12 hours after the addition of reagent.)

The adenylic acid showed no evidence of decomposition in the presence of ascorbic acid reagent (readings for samples treated "as for inorganic phosphate" are typical of reagent blank solutions). On digestion of the samples however, phosphate was quantitatively recovered. Adenylic acid was chosen for the test since it is one of the more stable phosphorylated products of biological activity, but it can hardly be regarded as one of the organic phosphorus substances found free in sea water since the exact nature of the latter is not known. It can only be assumed that stable organic phosphates which may be present in sea water will not cause appreciable errors in inorganic phosphate determinations if they do not decompose within 12 to 19 hours after the addition of reagent.

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NOTE ON CORRECTING G. E. K. OBSERVATIONS OF FLORIDA CURRENT OFF MIAMI FOR TIDAL CURRENT¹

FRANK CHEW AND L. P. WAGNER

ABSTRACT

A likely orientation of the tidal wave crest across the Florida Straits from Miami Beach to Cat Cay is suggested. Comparison of estimated and observed magnitudes indicates that the large transverse component observed in the Straits cannot be accounted for by tidal current. The tidal transport is shown to be about 2.3 million cubic meters per second. An approximate method is suggested for the correction of north component of observed current for tidal current.

INTRODUCTION

The many Geomagnetic Electrokinetograph (G. E. K.) transects across the Florida Current off Miami made by this Laboratory have frequently revealed large transverse components in the current which remain even in an average picture as shown by Hela and Wagner (1954). They think these average transverse components in the surface current are caused primarily by wind stress. In addition it was also shown by them that the northly component of the mean speed of the Florida Current is at a maximum with low tide and at a minimum with high tide at Miami Beach. This last conclusion is of particular interest for it apparently implies that the land boundary of the Florida Current off Miami is not a poor conductor of electricity. It has been shown elsewhere (Malkus and Stern, 1952) that when the sea bed is a non conductor the G.E.K. will not detect tidal current. Thus all G.E.K. measured currents off Miami, in addition to being subject to such uncertainties as those due to vertical and horizontal velocity shears, are further subject to the uncertainty of tidal influence. It is the purpose of this note to estimate the magnitude of this tidal uncertainty by (a) an estimate of the magnitude of the tidal current in relation to individual G.E.K. observations, (b) an estimate of the tidal current transport through the Straits off Miami and (c) a formulation of an approximate method for the tidal correction of the north component of the Florida Current as observed by the G.E.K. The authors are indebted to Dr. Ilmo Hela for several useful suggestions.

¹Contribution No. 131 from the Marine Laboratory, University of Miami.

PROCEDURES

Estimated Magnitude of Transverse Component of Tidal Current.

Ideally, the magnitude of the tidal current is best obtained by a long series of actual measurements. But for the Florida Current this approach offers dubious practicality. For the practical problem would be the derivation of a small quantity as a difference of large quantities since the Florida Current is some 10 or more times greater than the tidal current.

There are no adequate ready-made theoretical tools available. The Kelvin wave is not applicable nor is the Sverdrup wave (Sverdrup, 1946: 556). Because of the relatively low latitude setting of the Florida Current and the containing effects of the Straits' walls, transverse current due to Coriolis force is probably small. The clockwise rotation due to Coriolis force is probably further reduced at the Miami side by the counter clockwise rotation of the tidal current due to the existence of shelving shores (Doodson, 1941).

However, the following two equations and the two sets of observations available appear to be sufficient for the present purpose.

The first applicable equation relates the speed of a free tidal wave propagation, C , to the water depth, H , and the elevation, h , of the tidal wave with respect to the mean level (See Lamb, 1945):

$$C = \sqrt{gH} \left(1 + \frac{3}{2} \frac{h}{H} \right) \quad (1)$$

In deep water h/H is generally negligible. The second equation relates the speed, u , of the water particles in a tidal wave, to these same parameters.

$$u = C \frac{h}{H} \quad (2)$$

The first useful set of observations is presented in Table 1, which is an extract from *Tidal Harmonic Constants* (TH.—1, USCG&S, 1942).

It is evident that the several semidiurnal component tides reached Miami Beach and Mayport, some 500 km north, almost simultaneously. This is possible only if the tidal waves were more or less parallel to the East coast of the Florida Peninsula. See Figure 1. But these same component tides also reach Cat Cay almost simultaneously, so that the approaching tidal wave appears to be oriented somewhat north-south along the Florida Peninsula, then curves sharply in the east-west direction in the vicinity of Miami Beach. The exact orien-

TABLE 1

	M_2		S_2		N_2		K_1	
	H_2 feet	G degrees	H_2	G	H_2	G	H_2	G
Miami Beach, Fla.	1.20	20	0.24	44	0.27	1	0.06	51
Cat Cay, Bahamas	1.11	20	0.23	49	0.26	356	0.06	52
Mayport, Fla.	2.14	23	0.38	46	0.46	0	0.10	56
Key West, Fla.	0.56	64	0.17	84	0.12	36	0.05	84

M_2 —Principal lunar semidiurnal constituent.

S_2 —Principal solar semidiurnal constituent.

N_2 —Larger lunar elliptic semidiurnal constituent.

K_2 —Lunisolar semidiurnal constituent.

H_2 —Amplitude of tidal wave.

G—Phase lag referred to the meridian of Greenwich.

tation of the tidal wave crest across the Florida Straits is not known, but the second available observation helps to define it. This observation is the conclusion reached (see Hela & Wagner, 1954) that the northerly component of the mean speed of the Florida Current is at a minimum during high tide at Miami Beach. This conclusion apparently implies that the crest of the free progressive tidal wave, with a tidal current opposing that of the Florida Current during high water, is oriented not far from the east-west direction across the Straits. This implication is in agreement with the consideration that because of transverse water movement high water cannot occur appreciably earlier in the deeper portion than it does in the shallow portion of the Straits.

A likely orientation of the tidal wave crest is suggested in Figure 2. The oblique movement of the wave crest may be resolved into a longitudinal component along the axis of the Straits and a transverse component normal to the axis. The longitudinal component will be dealt with in the next section, and the transverse component will be assumed to cause the transverse tidal current. The transverse component of the wave crest, which is thought of as a free wave, will propagate according to equation (1) where the value H shall be taken to be the actual water depth at the point of interest. The magnitudes of C and u according to equations (1) and (2) respectively are computed for a number of points east of Miami Beach to Longitude $79^\circ 49' W$ where the transverse component is assumed to be zero (Table 2). This choice is arbitrary, but any other reasonable choice makes no significant difference. If this were a standing tidal wave, then

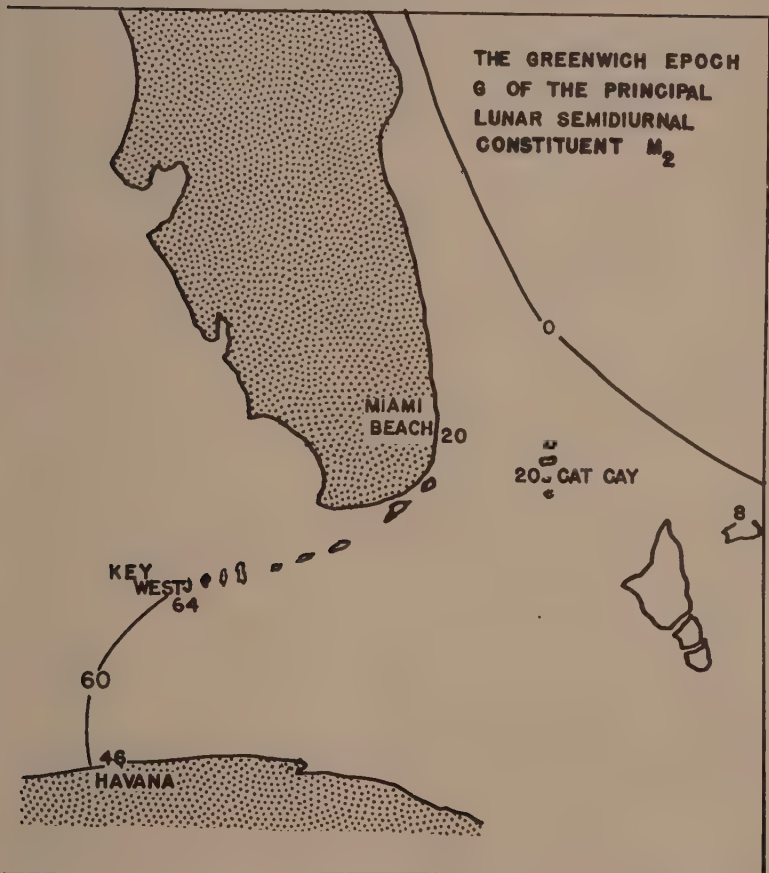


FIGURE 1

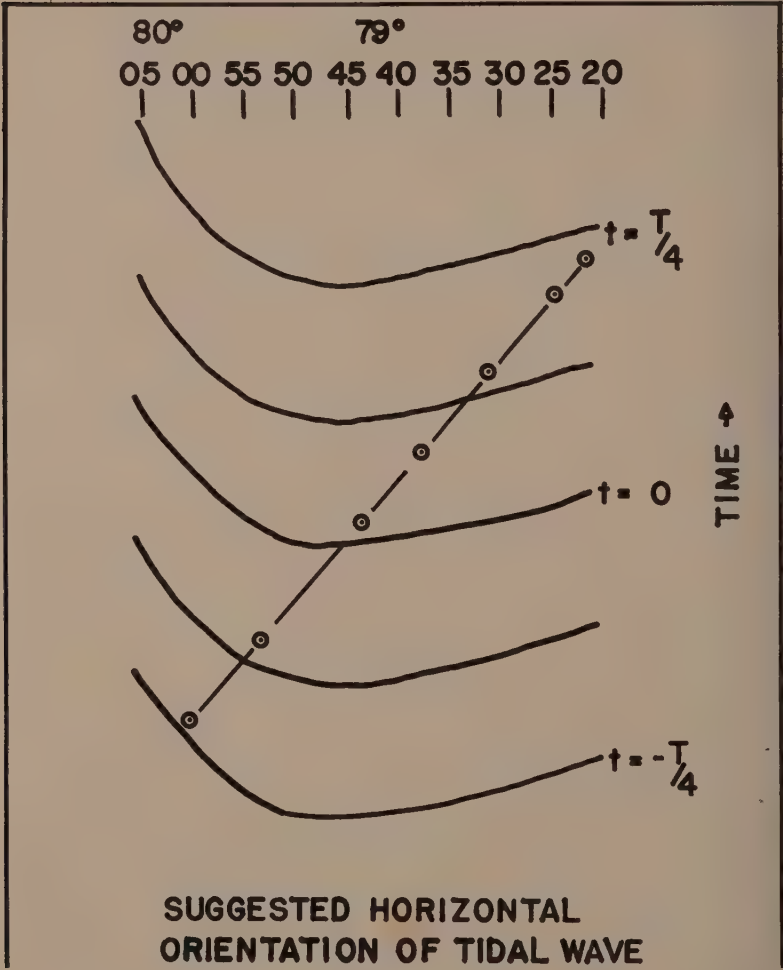


FIGURE 2

the maximum movement of its water particles, as denoted by V would be even smaller than the maximum movement of water particles in a progressive tidal wave, as denoted by u . This may be seen in Table 2. An evaluation defining V is found in Sverdrup (1946: 567).

TABLE 2
TRANSVERSE TIDAL CURRENT u

Longitude	80°								79°					
West	07'	06'	05'	04'	03'	02'	01'	00'	58'	56'	54'	52'	50'	
H(meter)	5.5	12	55	110	220	240	260	275	290	290	295	330	550	
C(cm/sec)	8.1	11.5	23	33	47	49	51	52	54	54	54	57	74	
u(cm/sec)	-58	-39	-17	-12	-8.5	-8.1	-7.8	-7.6	-7.5	-7.5	-7.4	-7.8	-5.4	
V(cm/sec)	-1.8	-1.6	0.5	0.4	0.3	0.3	0.3	0.3	0.4	0.4	0.5	0.5	0.3	
h	40 cm for all entries (high water phase)													

With the chosen orientation of a tidal wave crest, the direction of the east-west components of the tidal current often coincides with that of the observed current. But the postulated magnitudes are generally much smaller than those observed. Take, e.g., Table 3, the G.E.K. observations made on Dec. 22, 1952, when the following east components were observed. Other pertinent information on these observations are given by Hela and Wagner (1954).

TABLE 3
TRANSVERSE TIDAL CURRENT DURING CRUISE T-240a

Longitude of observation positions	Observed east component (uncorrected) (cm/sec)	u from Table 2 and similar computations not reproduced	Estimated east component of tidal current encountered (cm/sec)
80°00'	-22	-7.6	-2.7
79°53'	-13	-7.6	-6.0
48.5'	7	0	0
43.5'	16	4.5	4.4
37.6'	15	4.4	3.8
31.1'	9	4.4	2.8
24.6'	22	4.5	2.3
21.4'	29	5.4	0.9

The phases of tide during the G.E.K. observations are indicated by circled dots on the diagonal line in Figure 2. The first G.E.K. observation was made at Longitude 80° 00' at nearly two lunar hours after low tide at Miami Beach. The values entered in the fourth column in Table 3 are obtained by multiplying the values in the third column by the cosines of the product of $2\pi/T$ and the corresponding phases of the tide along the path of the observations (T is the period of tide).

It would appear from Table 3 that the estimated transverse tidal current is considerably less than the observed. An orientation of the wave crest which allows for a much greater horizontal curvature, besides being less probable because of transverse water movement, would neither improve on the magnitude or direction coincidence for the change of tidal phases encountered is not significant. An orientation which allows for less horizontal curvature is equally useless in this sense. The conclusion appears to be that the large observed transverse components in the velocity of the Florida Current cannot be accounted for by the transverse component of tidal current.

The Longitudinal Component of Tidal Current and the Tidal Transport in the Florida Straits off Miami. The tidal current being uniform from surface to bottom brings about considerable transport in the Florida Straits. Since the tidal wave is thought of as a free wave, this transport is maximum during high or low water. The G. E. K. transect of Cruise T-240a, Dec. 22, 1952, was made during the period approximately three lunar hours before and after high water (see Figure 2), hence the transport computed on the basis of observed G. E. K. values must be increased to account for the opposing, south-flowing tidal current encountered at the time of observation.

Figure 1 is a plot of the M_2 constituents in Table 1. If the equilibrium tide can be assumed to occur simultaneously over this region, then the Greenwich Epoch G can be considered as the time of arrival of high water. The tidal wave is then seen to reach Miami Beach and Cat Cay from the Atlantic basin at the same time and to progress south and then west. The difference in G between Miami Beach and Key West is 44 degrees or it takes 1.5 hours for the progressive tide wave to reach Key West from Miami Beach. From equation (1) H is 210 meters and from equation (2) u is 9 cm/sec for $h = 0.4$ meters. Similar treatment for Cat Cay to Havana gives H as 830 meters and u as 4.5 cm/sec. Again $h = 0.4$ meters. These values of u are for low water; at high water they are, of course, negative with respect to the direction of the Florida Current.

The 9 cm/sec speed may be taken to apply from $80^\circ 03'$ to $79^\circ 52'$, the meridional extent of the Blake Plateau. From $79^\circ 51.9'$ to $70^\circ 47'$, where the bottom of the Straits deepens steadily, the maximum longitudinal tidal current is assumed to decrease linearly from 9 cm/sec to 4.5 cm/sec. Eastward from $79^\circ 46.9'$ to $79^\circ 22'$, 4.5 cm/sec will apply. The cross section of the Straits between the above intervals are given in Table 4.

TABLE 4
TIDAL TRANSPORT

	80°03' - 79°52'	79°51.9' - 79°47'	79°46.9' - 79°22'	Total
Cross Section	$5.7 \times 10^6 \text{ m}^2$	$5.0 \times 10^6 \text{ m}^2$	$31.9 \times 10^6 \text{ m}^2$	$42.6 \times 10^6 \text{ m}^2$
Maximum transport m^3/sec	51.3×10^4	33.8×10^4	143.5×10^4	2.3×10^6
Maximum tidal current cm/sec	9	6.75	4.5	

The cross sectional areas do not include the small areas at both edges of the Straits but the transport value is affected only in the hundredth place by this exclusion. The maximum transport of the tidal current in the Straits is seen to be near $2.3 \times 10^6 \text{ m}^3/\text{sec}$.

A Method for the Tidal Correction of the North Component of the Florida Current off Miami. The methods and results of the two preceding sections can be put to this use immediately and no additional approximations are necessary. The tidal phases encountered during the G.E.K. observations can be estimated from a diagram such as Figure 2. The amplitudes of the longitudinal tidal current probably encountered are given as Maximum Tidal Current in the last row of Table 4. As an illustration, the tidal correction of the north component of the Florida Current as observed by the G.E.K. during Cruise T-240a is taken:

TABLE 5
NORTH COMPONENT AND TIDAL CORRECTION

Observed north components (cm/sec)	Maximum tidal current (from Table 4) (cm/sec)	Estimated longitudinal component of tidal current encountered (cm/sec)	Observed north component corrected for tidal current
59	9	plus 3	62
74	9	plus 7	81
106	6.75	plus 4.5	110.5
127	4.5	plus 4	131
104	4.5	plus 3.5	107.5
82	4.5	plus 3.3	85.3
46	4.5	plus 1.5	47.5
8	4.5	plus 1	9

SUMMARY AND DISCUSSION

The conclusion reached by Hela and Wagner (1954) that the mean speed of the Florida Current fluctuates tidally is taken to mean that all individual G.E.K. measurements contain tidal stream components, whose probable maximum magnitudes form the subject of this note.

A likely orientation of the tidal wave crest across the Florida Straits from Miami Beach to Cat Cay is suggested. The suggestion is based on previous works on tidal harmonic constants and average northerly speed on the Florida Current with respect to the tidal phases at Miami Beach. On the assumption that the north-south component of the wave crest propagates transversely according to $C=\sqrt{gH}$, where H is the actual water depth, the transverse components of the tidal current are obtained through equation (2). The transverse components so obtained are practically independent of the orientation of the wave crest and are probably the maximum possible values, since for free progressive wave there can be no resonance. While the direction of the transverse components resulting from the suggested orientation often agrees with observed directions, the magnitudes are considerably less, and hence it is concluded that the large surface transverse component of the current observed in the Florida Straits can not be accounted for by tidal current.

The longitudinal tidal current is shown to effect a maximum transport through the Straits of the order of $2.3 \times 10^6 \text{ m}^3/\text{sec}$.

These results are then further utilized to formulate an approximate method for the tidal correction of the north component of the Florida current as observed by the G.E.K.

It should be noted, however, that at the present stage of knowledge in the use of the G.E.K., it is not known how much of the tidal transport or tidal current is actually measured by it. Hence the correction of the current and computed transport based on G.E.K. values is uncertain in this sense. The values in the third column of Table 5 are based on the G.E.K. measuring the full magnitude of the tidal component. Even with this assumption the corrections are relatively small and for most purposes, best disregarded.

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THE TAXONOMIC POSITION OF *GOBIOCLINUS* *GOBIO* AND *CTENICHTHYS INTERRUPTA*, •TWO NAMES FOR BLENNIOID FISHES

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The specific names *Clinus gobio* Cuvier and Valenciennes and *Ctenichthys interrupta* Howell Rivero represent the type species of the nominal genera *Gobioclinus* Gill and *Ctenichthys* Howell Rivero. We believe that both generic names are synonyms of the genus *Labrisomus* Swainson. Hubbs (1952 and 1953) did not discuss *Ctenichthys* and erroneously considered *Gobioclinus* as a possible synonym of *Tripterygion* Risso.

Gobioclinus gobio.

Cuvier and Valenciennes (1836: 292) proposed the name *Clinus gobio* for five specimens sent from the Antilles by M. Pléé. Gill (1860) proposed *Gobioclinus* with *Clinus gobio* as type species. As he listed no additional specimens, he must have based his generic name on Cuvier and Valenciennes' description. Mocquard (1889), who presumably examined the types, recognized *Gobioclinus* as a valid genus, although he placed in the genus *Clinus* all species that are currently recognized to be in the genus *Labrisomus*. Longley (see Longley and Hildebrand, 1941: 257) examined the types of *Clinus gobio* and found one specimen of a *Labrisomus* species and four which he considered to represent *Tripterygion jordani* (Evermann and Marsh). He selected the labrisomine as the lectotype for the name *Clinus gobio*. Hubbs (1952: 102) unaware of Longley's action referred the name to the Tripterygiidae, and (1953) reaffirmed his action. Schultz (1950) did not consider *Gobioclinus* in his discussion of genera related to *Tripterygion*.

A comparison was made of the original description and the two species to which the name *Clinus gobio* might be applied. M. Bertin of the Museum National D'Histoire Naturelle kindly examined the five types. He reports that they are in bad condition. He was able to answer most of our questions on the single labrisomine, but unable to get any pertinent data from the four smaller tripterygiids. When William H. Longley designated the lectotype, he took notes on its morphology. Wherever possible, both Bertin's and Longley's characteriza-

tions are given. Longley did not characterize the four *Tripterygion jordani* specimens; apparently they were in too poor condition in 1935, the time of his visit. We base our characterization of that species on the original description by Evermann and Marsh (1899) and the account in Longley and Hildebrand (1941).

We believe that the original description was derived from specimens of both species. This conclusion is based on the following statements in Cuvier and Valenciennes. (1) *Il y a un très-petit tentacule au sourcil, qui disparaît aisément dans certains individus . . .* Labrisomine specimens have much more prominent supraorbital cirri than do those of *Tripterygion*. This character apparently is based on both species. (2) *Le crâne est un peu aplati*. The rough head of tripterygiids fits this description; the smooth-headed labrisomine specimens do not. (3) D. XVIII, 9. The labrisomine type has XVIII dorsal spines and 10 (Bertin) or 11 (Longley) soft dorsal rays. All specimens of *Tripterygion jordani* have three separate dorsal fins: the first two all spines and the third all soft rays; the total number of dorsal spines is XIV or XV; the number of soft dorsal rays is 7 (Evermann and Marsh), 8 or 9 (Longley and Hildebrand). The dorsal ray count agrees better with labrisomine figures. (4) A. II, 17. The *Labrisomus* specimen has 18 (Bertin) or 19 (Longley) soft anal rays. *Tripterygion jordani* specimens have 15 (Evermann and Marsh), 16, 17, or 18 (Longley and Hildebrand). The anal count is more likely to have been made from one of the tripterygiids. (5) *Les écailles sont assez grandes: il n'y en a guère que trente sur une ligne longitudinale . . .* Longley's published account lists 48-49 scales of the *Labrisomus* specimen (his notes give the count as 50); Bertin reported that the scales were so nearly lost that the count was not ascertainable. *Tripterygion jordani* specimens have lateral line counts approximating 33 scales. The lateral line count probably was based on a tripterygiid. (6) *Il n'y a de ligne latérale sensible que jusque vis-à-vis la fin de la pectorale, au tiers supérieur de la hauteur*. Labrisomine fishes have a prominent and high lateral line from the head to the end of the pectoral, at which point the lateral line becomes less obvious as it descends to the midline, on which it extends to the caudal peduncle. Specimens of *Tripterygion jordani* have a high lateral line that extends from the head to a point above the pectoral fin. It is then interrupted to run much less obviously along the midline. Although it is probable that the lateral line description was based on the tripterygiids, it is possible that the labrisomine specimen was used. (7) *Mais il a une*

bande très-brune à la base de la caudle. The labrisomine specimen appears to have had a dark band on the caudal peduncle, and freshly preserved specimens definitely have one. Tripterygiids frequently have a dark band there. Either species might have been used for the color pattern.

Inasmuch as the original description does not exclude any of the five specimens from consideration as the type of *Clinus gobio*, Longley's designation of the labrisomine must be followed. Although two of the characters, head texture and scale count, fit the tripterygiids better than the labrisomine, the dorsal count clearly can not be from a tripterygiid. Mocquard (1889) presumably examined only the tripterygiids, but did not designate one of them the type. The extremely poor condition of the tripterygiids favors selection of the labrisomine. As there is no other available specific name for the labrisomine it has a valid nomenclatorial rank if *Clinus gobio* is used for it. Because the tripterygiid apparently is the same species as that fish Evermann and Marsh later named *Gillas jordani*, confusion might result if the tripterygiid is selected as type. This would become particularly complicated if the form now known as *Tripterygion jordani* is found to be a complex. The differences between the counts of fishes from Porto Rico listed by Evermann and Marsh and those from Tortugas fish given by Longley and Hildebrand indicate a complex.

Labrisomus gobio is most closely related to *Labrisomus bucciferus* Poey. Both species belong in a subgroup that includes *Labrisomus kalisherae* (Jordan), the type species of *Ericteis* Jordan. Hubbs (1952) considered *Ericteis* to be a valid subgeneric name. As *Gobioclinus* Gill has priority over *Ericteis* Jordan, the subgeneric name, if valid, should be changed.

Only five specimens of *L. gobio* were discussed by Longley. They were collected from the Antilles and the Bahamas. No additional specimens have been recorded in the literature—Fowler's (1947) record apparently was based on *L. bucciferus*—. Five additional specimens (UM 844) from Cay Sal Bank, Bahamas are deposited in the Zoological Collections of the Marine Laboratory, University of Miami.

Labrisomus gobio differs from *L. bucciferus* in having a shorter maxillary, larger eye, blunter snout, shorter penultimate dorsal spine, color spokes behind eye, and in never having the color bars of the body extending onto the anal fin.

Ctenichthys interrupta.

Since the original proposal of this name by Howell Rivero (1936), it has not been used. Independently we concluded from the original description that this name is based on a *Labrisomus* specimen. As we are not able to determine the specific identification from the original description and we are unable to examine the type, our conclusion is based on information kindly supplied by Myvanwy M. Dick and William C. Schroeder of the Museum of Comparative Zoology. Their examination confirmed our suspicion of errors in the original description, *i.e.*, the type has vomerine teeth.

The type description and data furnished by Mrs. Dick and Dr. Schroeder lead us to the conclusion that *C. interrupta* is most probably a synonym of *L. bucciferus*. The coloration described by Howell Rivero excludes *L. gobio* from consideration. It definitely belongs to the same subgenus as *L. gobio* and *L. bucciferus*, but as yet it is not possible to define the limits of this subgenus.

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